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for March, 1937

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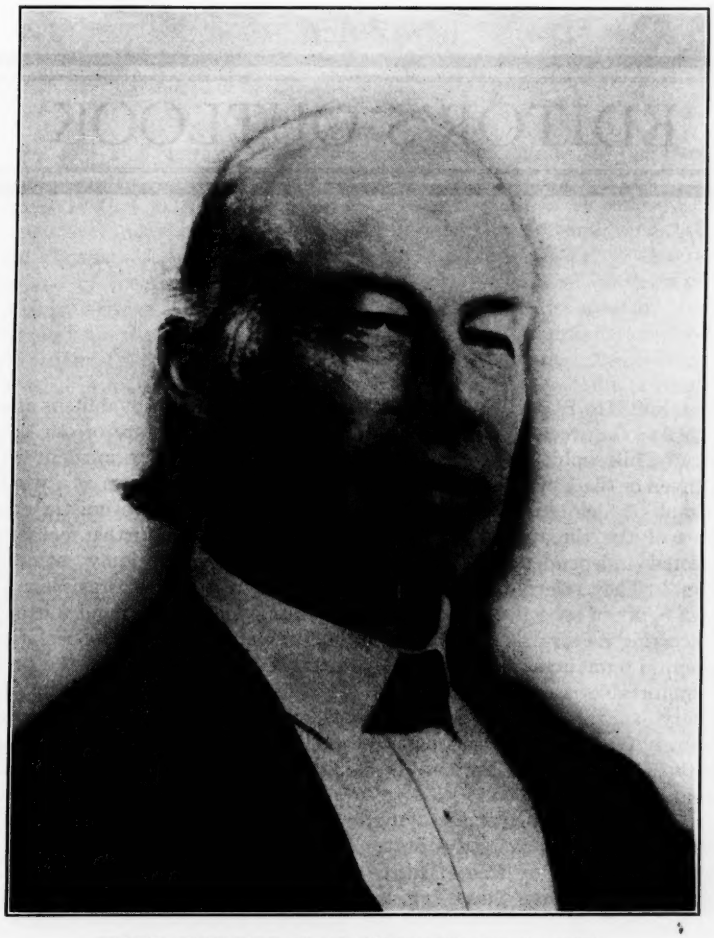

KARL REMIGIUS FRESENIUS (1818–1897)

Born at Frankfort-on-Main. Studied at Bonn and Giessen. At Giessen served as assistant in Liebig's laboratory and became assistant professor. Appointed to chair of chemistry, physics, and technology at the Wiesbaden Agricultural Institution (1845). First director of chemical laboratory established at Wiesbaden by the Nassau government (1848). Texts on qualitative analysis (1841) and quantitative analysis (1846). Many papers published in *Zeitschrift für analytische Chemie* which he founded in 1862 and edited until his death.

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EDITOR'S OUTLOOK

CLINICAL NOTE ON THE BODIES POLITIC AND ACADEMIC. At the recent Philadelphia meeting of the American Philosophical Society, President Alexander G. Ruthven of the University of Michigan and President Frank Aydelotte of Swarthmore warned their colleagues of the threats to "academic freedom and institutional independence" now "developing on our horizon." They referred, of course, if we may employ our own figure of speech, to the alarming growth and ever-recurring metastasis of the malignant tumor of governmental bureaucracy.

Unfortunately, the comfortable assumption that these gentlemen are visionary alarmists or irresponsible publicity seekers is scarcely tenable. On the contrary, it would appear that their statement of the case is a model of restraint and understatement.

The New York Times quotes Dr. Ruthven as saying, "I wonder if you realize that only two of the State-supported institutions [of learning] are free of supervision by State agencies, including the State Legislatures. This situation has had an astonishingly rapid rise in the last ten years. I mention it simply to develop the further thought that day by day we see the Federal Government taking over more supervision of State-supported education."

A genuine pessimist might well fear that the entire organism of our national life is already endangered, and that the eventual fate of our educational institutions will be but a minor incident in, or consequence of, the fate of the organism as a whole. These gentlemen, however, are still optimistic enough to believe that there is yet hope if further metastases can be prevented.

Fortunately, we know something of the various mechanisms of metastasis in this case. The one against which we can and must guard begins with the inducement of a sense of isolation in the organ to be attacked. Then there is the proffer of benefit at the expense of some remote organ, or of the organism as a whole, with which the threatened part now no longer feels any community of interest. The benefit offered may be illusory, and can be at best ephemeral, but that makes little difference. Invariably some concession is demanded in return for the spurious gift offered. If the invasion is successful, the process recurs elsewhere.

Dr. Aydelotte, as reported by *The New York Times*, sees our endowed institutions as loci which may still withstand this insidious infiltration if they awake to their danger in time. "The very freedom of endowed universities," he adds, "has affected the freedom of State Universities and, if the endowed institutions give up, they can no longer bolster the State school."

Beware of governmental agencies offering subsidies.

A SKETCH *of the* LIFE *and* CHEMICAL THEORIES *of* DR. EDWARD BANCROFT*

C. A. BROWNE

Bureau of Chemistry and Soils, Washington, D. C.

SO MUCH has been said and written about the perfidious and dishonorable diplomatic career of Dr. Edward Bancroft† that his contributions to science have been largely overlooked. He was one of the most distinguished chemists of his day, a Fellow of the Royal Society, and of the American Academy of Arts and Sciences, a close friend of Benjamin Franklin and Joseph Priestley, and the author of an epoch-making book upon the chemistry of dyestuffs, which is even now consulted with profit by specialists in this field.

From the meager accounts of Bancroft's early life, which are available, it appears that he was born at Westfield, Massachusetts, on January 9, 1744. According to a statement attributed to John Adams he was a pupil of the famous Silas Deane when the latter was a Connecticut schoolmaster, but afterward when apprenticed to a trade, young Bancroft broke the contract and ran away to sea. After several adventurous years he went to England where he studied medicine and acquired an M.D. degree, perhaps at Edinburgh where a younger brother afterward pursued a similar course of study. After graduating in medicine Bancroft went to Dutch Guiana where he lived for several years, presumably in the practice of his profession, but his time was also partly occupied in studying the natural curiosities of the country and the manners and customs of its natives. In 1766 he wrote to his brother four letters on these subjects. After his return to England they were published in 1769 in book form under the title:

"An Essay on the Natural History of Guiana in South America. Containing a Description of many curious Productions in the Animal and Vegetable Systems of that Country, together with an Account of the Religion, Manners and Customs of several Tribes of the Indian Inhabitants. Interpreted with a Variety of Literary and Medical Observations. In several Letters from a Gentleman of the Medical Faculty during his Residence in that Country."

The letters in this volume are interesting documents and disclose in their author an observing scientific attitude of mind. In his second letter he devotes eight pages to an account of the so-called "torporific eel" in which he disproves Reaumur's hypothesis of muscular action and demonstrates that the shock produced by this eel is electrical in its effect. The developing chemical interests of the twenty-two-year-old author are displayed in his fourth letter where he describes the methods employed by the natives of Guiana in making the Woorari arrow poison, also known as curare, a subject which interested Humboldt some forty years later. Bancroft's description of the chemical characteristics of this poison (p. 291) are among the earliest in the literature.

The year 1769 saw also the publication of another interesting work by Bancroft which was his:

"Remarks on the 'Review of the Controversy between Great Britain and her Colonies' in which The Errors of its Author are exposed and the claims of the Colonists Vindicated, upon the Evidence of Historical Facts and authentic Records.

"To which is subjoined a Proposal for terminating the present unhappy Dispute with the Colonies; Recovering their Commerce; Reconciliating their Affection; Securing their Rights; and establishing their Dependence on a just and permanent Basis. Humbly submitted to the Consideration of the British Legislature."

In this publication Bancroft not only criticizes the hostile policies of Chancellor George Grenville (author of the Stamp Act) regarding the American colonies, as expressed in the pamphlet entitled, "Review of the Controversy between Great Britain and her Colonies," but submits a proposal to Parliament by which the affection of the colonies might be regained. Bancroft in this publication shows himself to be a true American and had his advice been followed the outbreak of the Revolution would no doubt have been prevented.

As a countryman and a fellow scientist, Bancroft had already won the friendship of Benjamin Franklin, at that time the London agent of Massachusetts, Pennsylvania, and other American colonies. Because the confidence of Franklin was further enhanced by Bancroft's published criticisms of Grenville's colonial policies, it was quite natural that he and Franklin's other scientific friend, Joseph Priestley, also a defender of the American colonies, should accompany Franklin

* Presented before the Division of History of Chemistry at the Ninety-first Meeting of the A. C. S., Kansas City, Missouri, April 14, 1936.

† See sketch and references about Bancroft in Dictionary of American Biography, also article entitled, "Arch-Traitor of the Revolution" by Burton J. Hendrick in Readers Digest for January, 1936, p. 46.

at the time of his famous hearing before the Privy Council on January 29, 1774. Priestley and Bancroft have each left accounts of the outrageous manner in which Franklin was abused at this meeting.

It was some three years after the Privy Council affair, following the outbreak of the Revolution, that Bancroft began his sinister double rôle of British and American spy. He was the trusted agent of Franklin and Deane, the two American commissioners to France, to whom he brought secret news from London. Congress paid him a salary for this service. At the same time he was transmitting to the British ministry information about the dealings of the American commissioners with the French Government concerning credits, treaties, and shipment of supplies. For this service he received 400 pounds per annum from the British Government which was later increased to 1000 pounds. The true extent of Bancroft's infamy was not revealed, however, until a century later when the British secret service reports during the Revolution were released in 1889. Franklin and Deane, although warned by their fellow commissioner, Arthur Lee, remained staunch believers in the integrity of Bancroft until the very end of their lives.

Omitting further references to these very disloyal diplomatic activities of Bancroft we will pass on to a discussion of his work upon dyestuffs for which he is best known to chemists. As a boy in America he was familiar with the tinctorial properties of the bark of the butternut and the juice of the poison ivy. His interest in dyes was further widened during his study of tropical plants in Dutch Guiana between 1765 and 1768. In 1769 after his return to England he became actively interested in the chemistry of dyes and calico printing in which subjects he began to make practical experiments. In 1770 he made another voyage to North and South America in the search of new dyestuffs. He became interested in America in the dyeing properties of the barks of the hickory, the red mangrove, and the black or dyer's oak (*Quercus tinctoria*) for the coloring principle of which Bancroft coined the name quercitron. While he was living at Surinam in Guiana he made dyeing experiments on linen with the juice of gardenia fruit.

After returning to England in 1771 Bancroft became convinced that quercitron was the most valuable of the new dyestuffs which he had investigated and engaged his brother, who was then studying medicine at Edinburgh, to go to America and begin work on extracting quercitron dye, the shipment of the raw bark being deemed too expensive. When extraction of the dye in America proved unsuccessful Bancroft finally had to resort to the importation of the bark itself. In the autumn of 1775 he received a shipment of twenty tons of quercitron bark from his brother in Philadelphia. Having received in 1771 a fourteen-year patent for the exclusive use of this new dye, Bancroft seemed on the point of establishing a lucrative business when the outbreak of the Revolution put an end to all his plans.

As soon as the terms of peace were signed between America and Great Britain in 1783 Bancroft set sail for the United States to look for his brother and to make arrangements for the renewal of his shipments of bark to England. He returned to England in 1784 and from now on, abandoning all thoughts of renewing his medical practice, devoted his energies to his dyestuff operations. In view of the interruptions of the war he was granted a fourteen-year extension of his patent on the use of quercitron bark by Parliament in 1785, but the infringement upon his rights by various dyers and calico printers considerably reduced the income which he hoped to derive from this monopoly.

In 1787 Bancroft edited a volume of Franklin's Philosophical and Miscellaneous Papers on chimneys, stoves, meteorology, economic conditions in the United States, the Indians of North America, and other subjects. A second volume of Franklin's papers was promised by Bancroft, but this was never published.

Bancroft's investigations in dyes led to the publication in 1794 of his well-known "Experimental Researches concerning the Philosophy of Permanent Colours and the best Method of Producing them by Dyeing, Calico Printing, etc." This was the first authoritative book upon dyestuffs in the English language, and the work enjoyed a wide popularity.

In 1798 Bancroft published his "Facts and Observations briefly Stated in support of an intended Application to Parliament" which contains his appeal for another fourteen-year extension of his patent in the use of quercitron bark. Much to Bancroft's disappointment, this application was denied and he was, therefore, obliged to seek financial income from other ventures. In the next few years he made business voyages, one to North and the other to South America, in both of which his activities were hampered by ill health.

After making his third and last visit to Guiana in 1805 he returned via Barbados to London where he spent the remainder of his days. Having found that the first edition of his book on "Permanent Colours" had been exhausted (second-hand copies selling for six times their original price) Bancroft devoted himself energetically to getting out a new edition of this work, in the preparation of which he conducted a large number of experiments. This enlarged second edition in two volumes of his "Experimental Researches concerning the Philosophy of Permanent Colours" was published in London in 1813. This was the last work from Bancroft's pen and the remainder of his life seems to have been spent in seclusion. He died at Margate on September 8, 1821, in the seventy-seventh year of his age.

Bancroft's book on permanent colours not only contains a vast amount of interesting historical information, but it shows its author to have been a man who was widely read and thoroughly acquainted with the chemical knowledge of his time. References to the work of Berthollet, Berzelius, Chaptal, Chevreul, Gay-Lussac, Pelletier, Senebier, Thenard, Vauquelin,

and other distinguished continental chemists are frequent in its pages. As a member of the Royal Institution Bancroft was acquainted with Davy, Rumford, Wollaston, and other prominent British chemists of his period. He speaks of them in the pages of his book and also of another celebrated London Chemist, Frederick Accum, from whom he bought reagents and equipment. In his discussion of the numerous conflicting chemical theories, which were then contending for supremacy, Bancroft showed absolute independence of judgment, daring to take issue with the most noted chemists of his time. He was not always fortunate, however, in estimating the worth of new chemical discoveries, and his pride of opinion led him into many errors. This is shown, for example, in the remarks in his preface (Vol. I, pp. viii–x) about the new chemical discoveries of Davy:

"I have not," he writes, "been convinced of the expediency of adopting some of the opinions recently promulgated by Sir Humphry Davy; though I hope and believe, that I am properly disposed to admire his extraordinary talents, and acknowledge the important additions made by him to chemical science. This is not the place to discuss, and, therefore, it would be improper to dispute any of his facts; but I hope it may not be deemed improper for me to mention a few of the objections to which some of his conclusions seem liable.

"He supposes himself to have proved that the fixed alkalies, (and several of the earths) are *metals* combined with oxygene, or, in other words, metallic oxides; and that when the oxygene has been separated by the powerful agency of opposite electricities, from the bases of these alkalies, the latter are reduced, each to its proper metallic state, and though the supposed *metallic globules* so produced, cannot be retained in this state for a single minute without burning, and again becoming potash and soda, and are besides much lighter than water, he has thought it right to consider and arrange them as *metals*, under the names of potassium and sodium. He, (Sir H. Davy), admits that 'a considerable degree of specific gravity was formerly considered as an *essential* character of metallic substances, but (he adds) I have discovered bodies lighter even than water, which agree in all *other* essential qualities with metals, and which *consequently must* be arranged with them.' (See 'Elements of Chemical Philosophy,' p. 319.) How it should follow that bodies which agree with metals in all but *one essential* character, *'must'* be arranged with them, I am unable to conceive: for to my understanding, an *opposite* inference seems the most natural, and, indeed, the only allowable one. But is it true that the bodies in question do really possess *all* the other characters which are deemed essential to the constitution of a metal? Is not the strong propensity of potassium and sodium to burn instantaneously in the air, and as instantaneously to decompose water, without acquiring in either case, the properties of metallic oxides, at *variance* with all former ideas of the nature and essential characters of a metal?"

". . . .There is, indeed, an additional reason for not considering in this work the alkalies as metallic oxides; which is, that *their effects in dyeing* are *as opposite as possible* to those of the oxides of metals, properly so called: and in regard to alumina, (or the earth of alum) which is supposed to contain a peculiar metal, called by Sir H. Davy *aluminum*, I must declare that the evidence or probability of its existence, appears to me much more feeble even than that which regards the supposed metals of the alkaline earths; which last, in my judgment, is far from being sufficient to warrant his arrangement of them in the class, and under the denomination, of metals.

"It will be seen, also, that in the following pages I have not adopted the name of *chlorine*, by which Sir H. Davy would distinguish that substance, which *Scheele* supposed to be muriatic acid, freed from hydrogene; and which Berthollet afterwards, with the general concurrence of modern chemists, declared to be muriatic acid, combined with oxygene; whence it was denominated oxygenated muriatic acid, and by abbreviation, oxymuriatic acid. Whether Sir H. Davy be correct in adopting Scheele's view of the nature of the oxymuriatic, and the muriatic acids, and in concluding, as he has done from his own experiments, that the former (chlorine) is a simple or elementary substance, and that the latter 'consists of hydrogene and chlorine in equal volumes'; or whether the French chemists, (in conceding to Davy, that no experiment has yet incontestably proved that oxymuriatic acid gas contains oxygene) are, notwithstanding, justified in concluding, that the theory which admits or supposes this to be the case, is more natural, and accords better with the whole *System* of chemical facts, than the opposite theory, is a question which seems to be yet attended with doubt and difficulty; and so long as any doubt remains on this subject, I think it best to abstain from such changes of names, of which there have already been but too many."

It will be seen that so far as Bancroft's criticisms of the new chemical theories of Davy are concerned with regard to sodium, potassium, aluminum, and chlorine he was wrong on every count, but before condemning him for this we must recognize that Berzelius, Gay-Lussac, and many other eminent European chemists maintained for a time similar points of view.

Bancroft prefaces his work on permanent colours with a glossary of chemical substances (pp. xv–xviii) which is interesting as an effort to define the newer nomenclature then coming into use in terms of the older phlogiston terminology which was still in vogue. Acetic acid, for example, is defined as "strong dephlegmated acid of vinegar," azote as "the phlogisticated air of Priestley," "Oxymuriatic Acid, or Chlorine of Davy" as "the dephlogisticated marine (or muriatic) acid of Sheele," etc.

In the division of his subject matter Bancroft recognizes two general classes of animal, vegetable and mineral dyes, first the substantive class such as Tyrian purple, indigo, and silver nitrate which color fibers directly without the use of mordants, and, second, the adjective class, which usually requires the use of fixing agents or mordants for producing the best shades and degrees of fastness.

Bancroft describes over one hundred different animal, vegetable, and mineral substances which were used as dyes, his historical and scientific accounts of indigo, cochineal, quercitron, lac, Tyrian purple, Prussian blue, logwood, and madder being especially voluminous. His descriptions of the salts of aluminum, iron, tin, and other metals which were used as mordants are also very complete. A final chapter of one hundred pages is devoted to the subject of writing ink. Bancroft was an authority on the subject of ink, but he says nothing in his book about the composition of the invisible white ink and the developer for this which were used in connection with his secret, perfidious messages to the British Secret Service.

It is impossible in this paper to give details of Bancroft's views upon the chemical nature of the different dyes which he describes. Something should be said, however, about his general theory of the chemistry of dyeing which constitutes the first chapter of his book.

In his search for the basic principle which was responsible for the tinctorial properties of all vegetable, animal, and mineral dyes, and after a thorough analysis of all previous views of the question, Bancroft came to the conclusion that the element oxygen was generally necessary as an ingredient of coloring substances. His conclusions are summarized in the following paragraph at the close of his first chapter (p. 82):

"Until further discoveries, therefore, shall have been made, I consider myself as only authorized to conclude, that the *permanent* colours of matter do not depend upon the thicknesses, sizes, or densities of its parts or particles, but upon certain affinities or attractions, physical, or chemical, by which it is disposed and enabled to absorb and conceal some of the rays of light, and to reflect or transmit other rays, producing the sensations or perceptions of particular colours; and that to the existence or energy of these affinities, or attractions, certain portions of oxygene are generally necessary, as a constituent part of colouring matters; and these portions may in some instances be increased, and in others diminished, by the influence of *radiant matter*, or solar light, which may thereby contribute to the production of some, and the destruction of other colours."

Believing that oxygen is the genetic agent in the production of color, Bancroft cites a number of arguments which seemed convincing (Vol. I, pp. 62–64). He lays great stress, for example, upon the need of atmospheric oxygen for converting colorless solutions of reduced indigo to the intense blue which is characteristic of the dye itself. The need of oxygen for generating the colors of orchil, turnsole, gardenia, and many other vegetable dyes, the necessity of atmospheric oxygen for converting the blue color of venous blood to the bright red of arterial blood, the rôle of oxygen in producing the varied colors of many metallic oxides, in intensifying the black color of ink and in promoting the tinctorial characteristics of Prussian blue and other mineral dyes, are all cited by Bancroft as proofs of the general function of oxygen in the production of color.

On the basis of his experiments some apparent exceptions to this general rule, such as the production of the color of Tyrian purple in a vacuum, are considered by Bancroft to be verifications, not refutations of his theory. He assumed in such cases that, oxygen was liberated by the action of sunlight upon certain oxygen-containing compounds that accompanied the dyestuff (Vol. I, pp. 148–158). To this supposed deoxygenating power of sunlight Bancroft attributes other color phenomena, such as the blackening of tissues stained with silver nitrate. After further loss of oxygen the dark-colored silver oxide which is formed becomes almost black (Vol. I, p. 327).

Bancroft's belief that oxygen is responsible for colors led him to draw some strange conclusions. In his opinion the color of charcoal (Vol. I, p. 56) was due to the combination of a hypothetical carbonaceous basis with oxygen. He reasoned that natural carbon could not be black; otherwise, its predominance in wood and other vegetable matter would give these materials a black color. Bancroft's theory that charcoal was an oxide of carbon was accepted for a time by Thompson and other chemists of the early nineteenth century.

Another example of the errors into which Bancroft's hypothesis led him is concerned with the various colorations produced by the decompositions and reactions of nitric acid. Nitric acid is colorless, but on exposure to the rays of the sun in an open vessel, according to the reasoning of Bancroft (Vol. I, p. 36)

". . . .the light will combine with a part of the oxygene and cause it to become elastic and fly off and the nitrogene will consequently predominate in the remainder; which, becoming *nitrous acid* merely in consequence of this predominance, will assume first a yellow then an orange and afterwards a high vivid aurora, and even a red color intensely affecting the sight. . . ."

"In the same manner, colourless nitric acid, when applied to wool, silk, fur, or the skins of animals, their nails, horns, etc. renders them all not only yellow, but orange, and even aurora-colored. M. Berthollet thinks these changes are produced by a kind of combustion; but I am persuaded they are the result of a combination of the oxygene with the nitrogene, which he has proved to be a constituent part of all animal substances; these changes being exactly similar both in their nature and origin, to the changes of colour produced as before mentioned in the nitrous acid. Were these colours the effect of combustion, why are they not likewise produced in the same manner upon linens and cottons, which are without nitrogene, but contain a great portion of the basis of charcoal, and ought therefore to be more liable to be acted upon in the way of combustion, than animal substances?" (Vol. I, pp. 37–38).

In the passage just quoted Bancroft falls into the same faulty method of reasoning by analogy for which he criticizes some of his predecessors. This highly deceptive method of deduction has been the trap, however, into which greater scientists than Bancroft have fallen. The yellow coloration produced by the action of nitric acid upon wool, silk, skin, and other animal substances, the so-called xanthoproteic reaction, was attributed in later times to the formation of picric acid, but even now the exact composition of the colored nitro-protein derivative, which attracted Bancroft's attention, is not perfectly understood.

The effect of reducing substances, such as sulfurous acid in bleaching the color of many natural dyes, Bancroft attributes to their property of withdrawing oxygen (Vol. I. p. 47) and this he advances as an additional argument for the correctness of his theory.

The fact that certain substances of high oxidizing power, such as oxymuriatic acid (chlorine), also bleach or destroy color, was advanced by Berthollet as an argument against the oxygen hypothesis of Bancroft. Nearly twenty pages (Vol. I, pp. 64–82) of Bancroft's book are given over to a rebuttal of this argument. The general tenor of his reply to Berthollet is that

". . . .though combinations of oxygene in certain proportions, are necessary to the existence of most, if not of all, colours, an excess of it may obstruct all manifestation or appearance of colour, as completely as the *total absence* of it does, in regard to indigo." (Vol. I, p. 80.)

The numerous experiments which Bancroft conducted on the variable effects of sunlight in producing and bleaching colors are of special interest to students who desire to trace the history of photochemical theories. Bancroft attributed these differences to the variable affinities of different substances. The amount of ab-

sorbed oxygen was increased in some cases and diminished in others. He then concludes:

"Should I be desired to assign a reason or cause for these affinities, and their connection with particular proportions of oxygene, I can only answer with M. de Buffon, that they who require the reason of a *general effect*, do not consider the infinite extent of nature's operations, nor the confined limits of human understanding." (Vol. I, p. 82.)

Bancroft's two-volume treatise on permanent colors is a most instructive work for those desirous of studying the tremendous flux of opposing chemical theories which took place at the beginning of the nineteenth century. As the historical information about different dyestuffs is quite complete, the work is one which can still be consulted with profit. The descriptions of experiments illustrate the rapid development of laboratory technic which occurred everywhere in the decades immediately following the pioneer discoveries of Lavoisier. While pride of opinion and a childish tendency to quote adulatory references to his own work detract somewhat from his treatment of the subject, Bancroft presents his material in a clear and logical style. Although the attempt to elaborate a general theory of the action of dyestuffs before their constitution had been established was premature nevertheless the effort was commendable. Bancroft's explanation was as good a one as could be formulated in the light of the chemical knowledge then available. His book must always be referred to by those who are studying the history of natural dyes.

AN INEXPENSIVE LAMP FOR ANALYTICAL BALANCE

H. E. PHIPPS

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ALL too frequently analytical balances are poorly illuminated for easy work, while the purchase of individual lamps is often too much of a financial drain when income is restricted. The following lamp is suggested as at least a partial solution to the problem. It can be made in a relatively short time by anyone handy with tools. Tin plate (a large tin can will do) is cut, hemmed, and soldered together as shown in the drawing and photograph. The feet (2) have slots cut in them so that they may be slipped under the head of the wood screws which serve to fasten them securely to the balance case. These feet are fastened at such a height (1) that the lamp bottom nearly touches the glass of the top balance window. Two $^3/_8$" holes (3) are drilled in the end opposite the receptacle for ventilation. A coat of aluminum paint inside and green or other color outside

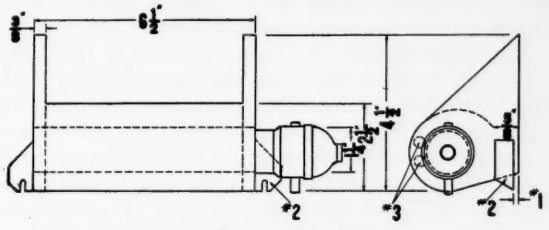

FIGURE 1.—PLAN OF LAMP

improves the appearance and utility and also protects the lamp housing from corrosion. A 25-watt tubular frosted bulb which is used for showcases is recommended, but an ordinary bulb may be used if the dimensions of the lamp housing are changed somewhat. However, the general illumination is not quite as satisfactory.

The necessary materials, which may be obtained from any dealer in electrical supplies, and their cost are as follows:

Tin Plate, 7" × 10" × $^1/_{32}$"	$0.04
Keyed Receptacle	0.20
Plug	0.05
Twisted Wire, 3 ft.	0.06
Bulb (frosted tubular showcase) 25-watt	0.35
Paint, about	0.05
Total	$0.75

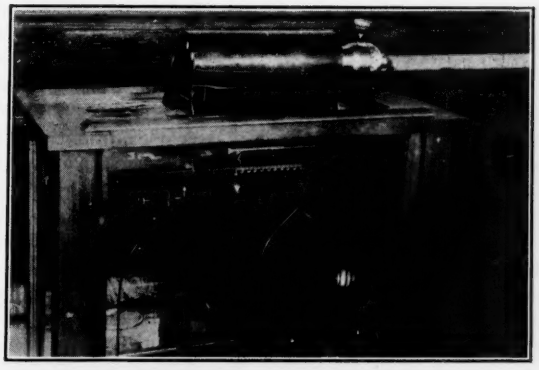

FIGURE 2.—AN INEXPENSIVE LAMP FOR THE ANALYTICAL BALANCE

Several of these lamps are being used in this laboratory with very satisfactory results.

I wish to express my thanks to Mr. Edson Clodfelter, engineer, who made the lamps and assisted in designing them.

The HELPFULNESS *of* OBJECTIVE TESTS *in* PHYSICS*

FREDERIC PALMER, JR.

Haverford College, Haverford, Pennsylvania

THE establishment of the College Entrance Examination Board marked a great step forward in the science of testing. It provides (1) identical entrance examinations for all colleges in a variety of subjects; (2) the examination in each subject is made out by a general committee instead of a local one; (3) this committee is composed of representative subject-matter experts from both schools and colleges; (4) the questions are graded by a group of trained readers who have nothing to do with selecting the questions. The system adopted by the Board has been perfected through the process of evolution to such a point that further significant advances must be looked for only by changing the system.

The chief criticism of the Board examinations has been and still is that they vary in difficulty so markedly from one year to another it is impossible to attach a definite rank to any score achieved by a student. One year only a quarter of the candidates may achieve a grade of sixty per cent. or better in a mathematics examination, while the next year *half* of the candidates may do so. Thus, the same grade, sixty per cent., represents high achievement on the first examination and low achievement on the second. If a representative committee of subject-matter experts can fail so completely in arriving at the correct estimate of the difficulty of the examination they set, how much more uncertain must we be, as individual teachers, in our estimate of the difficulty of the tests we administer to our classes!

I wonder how many of you have undergone the same torture that I experienced a few years ago. I spent about five hours preparing a mid-year examination for a class in general physics and was well satisfied with the result. The next day I read over my questions and was disgusted to find that the paper was a much easier one than I had intended to set. Two days later I looked it over again and was horrified to discover how *difficult* it was. I finally asked the advice of my associate, telling him that I was sure it was either too easy or too hard, but I could not tell which. He said he thought it about right. But he was wrong. The results showed it was too hard. In the case of an examination of the usual type the proof of the pudding is, and can be *only* in the eating. When indigestion unexpectedly results we hasten to apply the usual remedy, that is, we raise or lower the actual grades in an arbitrary manner until they are about what we think they should be. Hence the student is not so far wrong when he refers familiarly to what we have done for him as follows: "He gave me a 75"; or "He didn't pass me." The tacit assumption that *he* could have passed me if he had wished has already covered the head of more than one college dean with white hair, since the parents quickly assimilate the point of view that the student has *less* to do with the grade he receives on an examination than the teacher.

Perhaps you will grasp the fact that I am trying to lay before you the deficiencies of the old, conventional type of examination—the kind grandfather used to make. Yes, that is my first point. Even when made out by a committee of the College Board the difficulty of such an examination cannot be predetermined; hence the same grade does not always measure the same achievement. When made out locally there is the *added* drawback that distrust and suspicion are engendered between student and teacher.

What, then, are the conditions to be satisfied by the ideal examination? (1) It must be fair; (2) it must cover the prescribed field; (3) it must minimize luck; (4) it must test factual knowledge, discrimination, and ability to reason; (5) it must be set at a predetermined known level of difficulty; (6) it must contain questions which are known to discriminate well between the good and the poor students; (7) it must be possible to duplicate in these respects from year to year; (8) it must be made by someone else than the local teacher.

Is it possible to devise examinations which satisfy all eight of these conditions? Yes, it is; and much has been written about the technics required to do it. These I shall enumerate very briefly.

(1) To be fair a test must comprise *many* questions. This fact is deducible from the laws of chance. Its importance is too often utterly disregarded by teachers. If many questions are to be answered in a short time, each question should require not over one minute to read, master, and answer. To meet this need there has been devised the objective type of question, a statement or problem followed by several possible answers, the correct one of which is to be checked by the student.

(2) The field to be tested is determined by examining in detail the subject matter in a dozen or more texts and confining the questions to material found common to all. Controversial subjects should be avoided. Special topics of local interest can be treated in a

* Contribution to the Symposium on Tests and Examinations, Kansas City Program, conducted by the Division of Chemical Education at the Ninety-first Meeting of the American Chemical Society, Kansas City, Missouri, April 14, 1936.

supplementary test, preferably of the subjective type; a practice to be thoroughly recommended.

(3) To minimize luck in guessing the correct option there are usually five choices offered for each question. Only one is correct. The others are decoys. Each choice has a real decoy value, no matter how silly it may appear to be, as shown by the number of students it entraps when used in a *preliminary* test.

(4) Since the most frequent criticism of the objective test is that it tests factual knowledge only, I should like to make it clear that objective items may be devised which test reasoning ability as well. This is more difficult because of the short time allowance assigned to each item. Many questions of this character, including numerical problems, will be found on our physics tests, and Professor R. W. Tyler has devised a more elaborate type of question for testing ability to reason which has been used in tests on chemistry as well as on biology. Hence, if a certain test can be *justly* criticized for lacking items which test reasoning ability, it is the committee in charge of constructing the test which deserves criticism rather than the character of the test itself. Don't forget that even the best of testing committees is human!

(5) I have already tried to point out that it is impossible to predetermine the difficulty level of any test, either subjective or objective, without "trying it on the dog." The technic for making such a determination is as follows: two hundred fifty items, let us say, are chosen and given to several hundred students at various times a year or more in advance of their publication in test form. The results are tabulated item by item. It will then appear that certain items are unsatisfactory for any one of a number of reasons; too hard, too easy, not discriminatory, more than one correct option, controversial subject, etc. Fifty such items are thrown out. The difficulty of each of the remaining two hundred items is determined by the percentage of right answers it evokes. A very difficult question receives a small percentage, and vice versa. Two sets of tests of one hundred items each are then compiled by selecting pairs of questions on the same topic of the same indicated difficulty and putting one of the pair on each test. Thus, the number of difficult items and the number of easy items on each test is known *beforehand*. Furthermore, two tests so constructed have the same average level of difficulty; hence, they are said to be *comparable*. One may be used one year and the other the next, or one may be used as a pre-test to determine the degree of proficiency each student possesses at the beginning of his course, and the other at the end to discover his improvement during the course. The degree to which comparability of tests can thus be attained and the study of improvement by means of pre-tests and post-tests I shall discuss a little later.

(6) The power of separating the "sheep from the goats" which is possessed by each test item is called its *validity*. To be valid an item must be answered correctly by those students whose *total* score is high and incorrectly by those whose *total* score is low. When expressed in appropriate units the validity index thus measures the discriminatory power of each item. An index of zero means that the item is answered correctly by as many poor students as good students. In compiling a test those items which the preliminary trial shows to have low validity indices are thrown out.

(7) The duplication of the level of difficulty and the validity of tests from year to year is thus possible by the use of the above technics. Whether a given test committee is successful in bringing about such duplication is another matter.

(8) That there is much to be gained by the use of a test compiled by some agency other than the local teacher is a controversial matter. The local teacher often feels that he has emphasized certain matters, has included special topics, has taught his class in accordance with his own methods to such an extent that he alone can make out an examination which is fair to them. Yet physics is physics, and chemistry is chemistry from Maine to California; and if his students "know their stuff" they should be as well prepared to answer the questions approved by a committee of experts as those of any other teacher. If such a test is used extensively throughout the country each teacher can then discover how his students, both as individuals and as a group, compare with others on a *national*, as opposed to a local, scale. This is a matter of much interest and may be a matter of much importance to individual students, for instance when making application for a graduate fellowship at another institution. A second advantage of the "outside" over the local test is that the feeling of bias and suspicion of unfairness on the part of the teacher is immediately removed from the students' mind. Both can coöperate whole-heartedly in preparation for a test constructed by an impartial agency. The difference in class attitude which this change sometimes brings about is often striking.

A criticism sometimes made of tests compiled by a single agency for general use is that such tests have a tendency to "standardize the course." I fail to see the force of such criticism. It is true, for example, that a course in general physics should cover the ground regarded as of fundamental importance by a group of recognized experts. But this ground is already defined when the teacher chooses his textbook. Further he can lay the emphasis where he will, and can, introduce other topics *ad libitum*. Hence, standardization cannot be laid at the door of the tests.

I have felt it necessary to discuss these technics of test-making, both because their importance is so often under-estimated by teachers who try to compile their own tests, and because the helpfulness of our physics tests to teacher and student alike depends so largely on the successful exercise of the technics described.

Let us now turn to the Coöperative Physics Tests for College Students. An examination of three recent tests shows that the items are divided almost evenly

between those which require chiefly factual knowledge and those which require chiefly ability to reason. I shall quote three of the latter type.

"A mass of 1 g. at rest on a horizontal frictionless surface is acted upon by a horizontal force of 1 dyne for 1 second. During this second, the mass (1) moves 1 cm., (2) has an average speed of 1 cm./sec., (3) increases its momentum 1 g. cm./sec., (4) receives an impulse of $^1/_2$ dyne-sec., (5) increases its momentum $^1/_2$ g. cm./sec."

This question had a difficulty rating of 42 and a validity index of 4; that is, it was answered correctly by forty-two per cent. of the students and discriminated well between good and poor students.

"A match stick 5 cm. long weighing 1 g. floats on a water surface where the surface tension is 73 dynes per cm. If, with its length horizontal, the match is now lifted free from the water, the *total* force necessary is (1) 250 dynes, (2) 730 dynes, (3) 1053 dynes, (4) 1490 dynes, (5) 1710 dynes."

The difficulty rating was 28 and the validity index 5; a harder item than the first and even more discriminating.

"If two lenses have identical shapes and sizes, (1) their focal lengths have no connection with their indices of refraction, (2) they must necessarily have the same focal length, (3) the one of smaller index of refraction has the shorter focal length, (4) they will form the same size of image regardless of their indices of refraction, (5) the one of larger index of refraction has the shorter focal length."

This item was the easiest of the three—difficulty = 69, validity = 5.

Options which are expressed numerically, as in the second item quoted, often include results which will be achieved by a student who makes one or another of the most common mistakes in solving the problem. Hence, a careless student will be misled into thinking that his answer is correct just because he finds it given as one of the options.

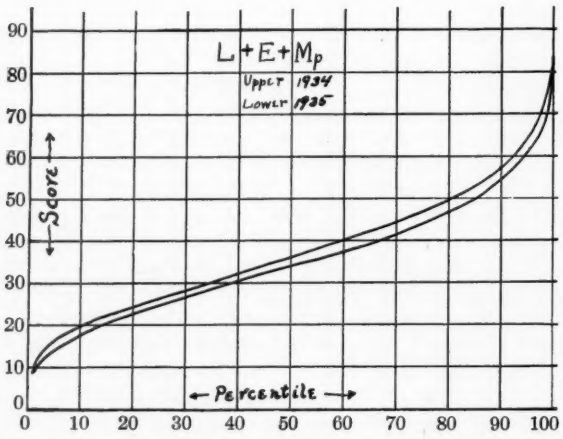

FIGURE 1.—PERCENTILE NORMS FOR SECOND SEMESTER TOPICS IN 1934 AND 1935

Simplicity in administering the tests is facilitated by compiling a separate test to cover each of the main branches of the subject matter. Three of these fall most naturally in the first semester—mechanics, heat, sound, and three in the second semester—electricity,

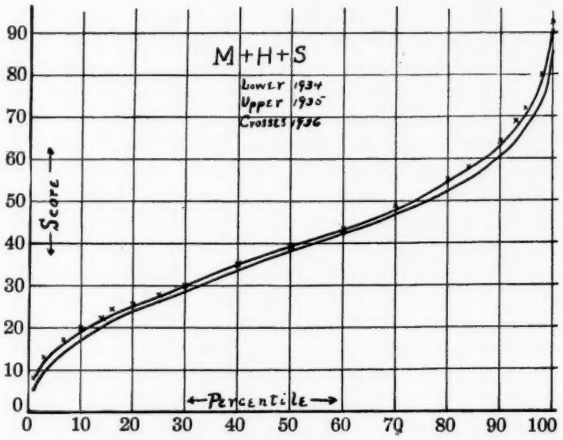

FIGURE 2.—PERCENTILE NORMS FOR FIRST SEMESTER TOPICS IN 1934, 1935, AND 1936

modern physics, light; but any teacher can use them in any order he wishes, or use some and reject others. The scheme is entirely flexible.

Each teacher is supplied with a strip of paper upon which the number of the correct response to each item is so spaced as to fall opposite the students' response when laid upon the test. Hence, scoring is simple, rapid, and uniform.

A copy of the scores achieved by his students is retained by the teacher who returns all used tests to the Coöperative Test Service in New York City. There the results are tabulated and studied, and a report covering the work of the previous year is issued each fall.

Results.—The first point of interest appears in a table of percentile ratings which shows the percentile corresponding to the score achieved on each of the six topics tested, and on the total of the three first semester topics, and of the three second semester topics. Since the total semester score is more significant than the score on a single topic I shall here consider total scores only. In Figure 1 appear data from the table of percentiles plotted in the form of a graph. The lower curve refers to the second semester tests of 1935, the upper curve to those of 1934. In 1934 we find that sixty per cent. of all students achieved scores between 0 and 40, inclusive, on the ninety-eight items in these three tests combined; eighty per cent. achieved scores between 0 and 49, inclusive. Hence, a student who scored 49 knows that he exceeded the score of 79 per cent. of all those taking the tests, in this case (1934) one thousand seven hundred fourteen students. In spite of the fact that these two sets of tests were not *paired*, as described in the technics of testing when they were constructed, they are nevertheless *nearly*

comparable, since the score achieved by a given per cent. of the students differs by not over two units at corresponding points on the two curves.

Figure 2 shows percentile ratings for the *first* semester topics, mechanics, heat, and sound, for the same two years. In 1934 the data were collected from 3741 cases. Here we find that the two curves run even closer to each other than before; hence, the tests were more nearly comparable. It is of interest to note that the results for 1936, just released, and here shown by crosses, lie so close to those for 1935 that a line drawn through them would be indistinguishable from that for 1935. In other words *complete comparability* was achieved.

Variability of Achievement.—You may be interested to inquire how closely the scores attained at any one institution would approximate those just shown for all

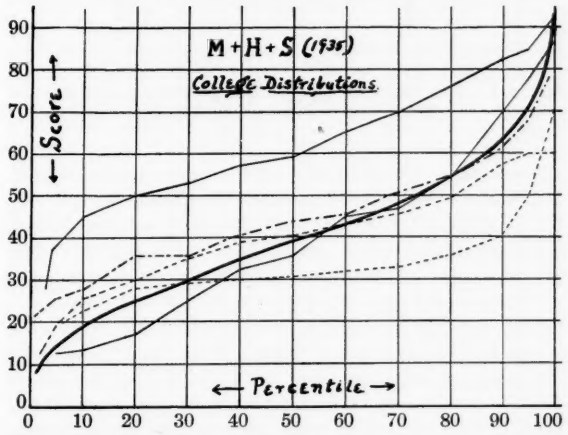

FIGURE 3.—COMPARISON OF RESULTS FROM INDIVIDUAL INSTITUTIONS WITH FIRST SEMESTER NORM (HEAVY LINE)
Two colleges for men (full lines)
Two colleges for women (dotted lines)
One university (dash-dot line)

institutions. We might anticipate that since standards of scholarship vary widely from one institution to another the curve for one college might lie well above and for another college well below the curve representing the results from all colleges. Data of this kind from a single institution have never been published because they are considered to be the private property of that institution. Nevertheless, for presentation on this occasion I have persuaded some of my friends to send me the results achieved at their respective institutions under the promise that I would not divulge the name of any institution. All the results (Figure 3) were obtained on the tests in 1935. Those for the first semester came from one university, two colleges for men, and two for women, as shown by the five broken lines. The smooth curve is the one previously shown for all institutions.

In Figure 4, which shows the results on the second semester tests, the curve for one of the colleges for women has been omitted. Since I alone know what colleges are here represented you will have to take my word for it that the general trend of each curve corresponds in a striking manner to the scholastic standard

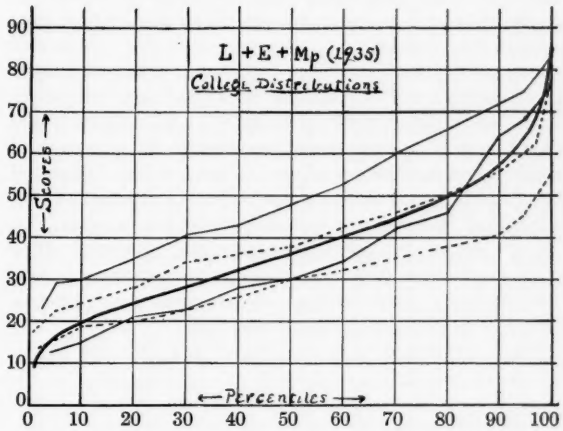

FIGURE 4.—COMPARISON OF RESULTS FROM INDIVIDUAL INSTITUTIONS WITH SECOND SEMESTER NORM (HEAVY LINE)
Two colleges for men (full lines)
One college for women (lower dotted line)
One university (upper dotted line)

we are accustomed, for entirely different reasons, to associate with each of these institutions.

Another way of representing the variability of achievement from one institution to another is shown in Figure 5. Each bar represents a single institution. The wide part covers the scores attained by the middle half of each group on M, H, and S in 1935. The narrow part extends to the 16th and 84th percentile, while the lines continue to the 10th and 90th percentile, and the crosses show the highest and the lowest scores. The short line which crosses each bar represents the median score. Every type of institution—university, college, engineering school, junior college, teachers' college—is included among these fifteen. All are supposedly of college grade. Yet the variation of the median percentile is from 88 to 6. What an astonishing difference in the standard of achievement in physics this represents! The highest percentile reached at college number 15 is the same as the lowest at college number 1. Nevertheless, it may well be that the students in college number 15 are receiving training more valuable to them, in view of their abilities, interests, and social needs, than mastery of physics.

A second type of variability is clearly set forth in this figure, namely, the variability, or "spread," within each institution, as shown especially by numbers 4, 6, 7, and 8. This spread is notably lacking in numbers 3, 5, 14, and 15. The same phenomenon is apparent in every such chart that has ever been drawn, irrespective of grade of institution and subject-matter field. This indicates the necessity for adjustment of course and pace to the needs and abilities of *individual* students within each college—an important problem which is difficult to solve.

Another glance at Figure 5 shows that at least one

student in each of seven of the colleges achieved a percentile rank of either 99 or 100. To each of these students this is an important item of information, since it shows that he is not only the ranking scholar at his own college but one of the top-notch men out of several thousand from all over the country. When he makes application for a scholarship or a graduate fellowship such an indication of scholastic achievement must carry weight to an extent impossible in the case of local recommendation alone. Often it has happened that the unusual ability possessed by a student of this kind has not been appreciated by his teacher, for there has been no means of comparing him with other good students. When once recognized, such a student may richly reward the special attention and guidance which a wise teacher should give him.

The variability in achievement in L, E, and MP is set forth similarly in Figure 6.

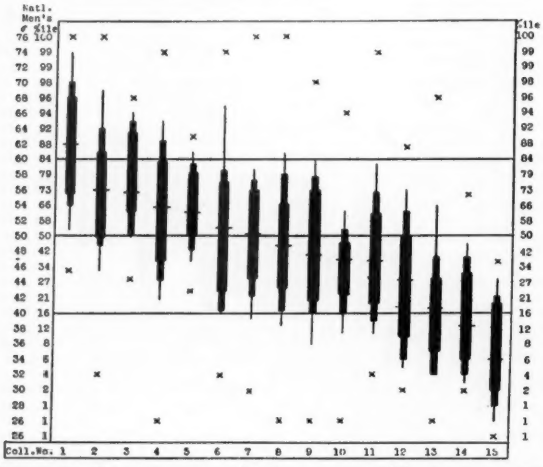

FIGURE 5.—VARIABILITY OF ACHIEVEMENT AS MEASURED BY THE COMBINED SCORES ON MECHANICS, HEAT, AND SOUND (M, H, AND S)

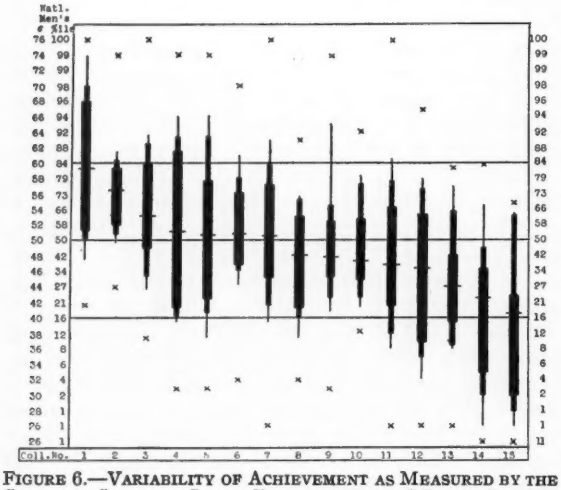

FIGURE 6.—VARIABILITY OF ACHIEVEMENT AS MEASURED BY THE COMBINED SCORES ON LIGHT, ELECTRICITY, AND MODERN PHYSICS (L, E, AND MP)

The information which is now available to the users of these physics tests has been found so valuable by

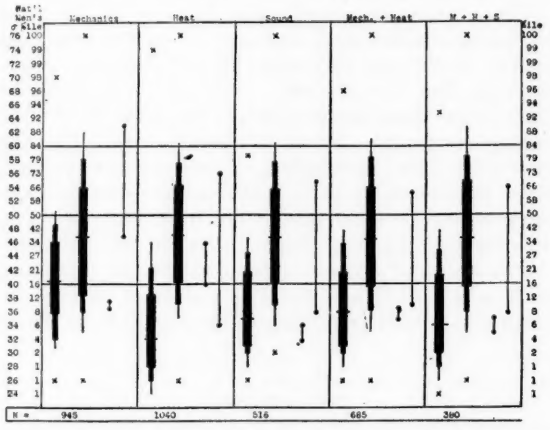

FIGURE 7.—PRE- AND POST-STUDY COMPARISONS FOR MECHANICS, HEAT, AND SOUND (M, H, AND S)

physics teachers that now five of the large eastern preparatory schools have adopted them, in spite of the fact that the items were prepared for the use of *college* students. The results add to the school record supplied when these boys apply for admission to college.

College Averages.—The report of our committee includes a table of college averages in each of the six topics and the semester totals. Thus, each college can discover its own standing relative to the others on these tests. This comparison may be stimulating both to colleges whose rank appears high and to those whose rank appears low. However, since this rank, as shown in the table, is not very significant, unless maintained over a period of years, the results should be interpreted with great caution. Hence, I shall pass over them without further discussion.

Gains in Achievement.—The existence of strictly comparable tests makes possible a new method of attacking an old educational problem—a study of the gain in mastery of a subject during the course. This requires the use of tests which are truly comparable. One test is taken at the very beginning and another, on the same topic, at the end of the course. The difference between the two scores may be regarded as a measure of the improvement achieved. In Figure 7 the two bars at the left of each section represent distributions of scores of all students who took both pre-tests and post-tests. The other two lines connect dots which show the pre-test and post-test mean for that college which has the smallest and that which has the largest gain in each topic. Few teachers are aware of the important fact that a few students at the *beginning* of the course are able to exceed the average of the whole class at the *end* of the course. In all but one of the topics shown ten per cent. of the students at the beginning secured scores which were above the class average at the end, as indicated by the median line.

Furthermore, at least one student in M and one in H ranked at the beginning with the highest five per cent. of the class at the end of the semester. It is obvious

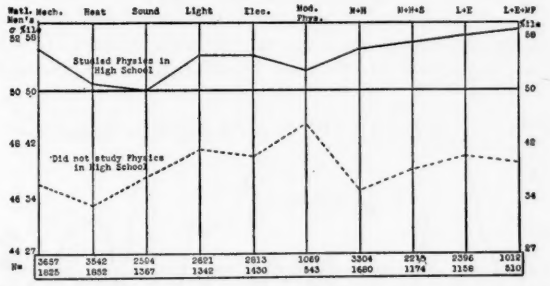

FIGURE 8.—COMPARISON OF PERCENTILES OF THOSE WHO STUDIED WITH THOSE WHO DID NOT STUDY PHYSICS IN HIGH SCHOOL

that early identification of such promising pupils is advantageous and that special attention and encouragement should be given to them.

The students at the other end of the scale also merit special attention. They are getting little for the money expended for their education (at least in physics) by their parents or by the state. Yet they may work harder than the majority and deserve something more than to be stigmatized as failures. Results such as those shown are a significant contribution to the experimental study of this difficult problem. Growth cannot be studied without comparable measures, hence the emphasis which has been placed upon the importance of developing and employing *comparable* tests in physics.

High-school Physics.—The value to the college student of a year's study of physics in preparatory school has long been a moot point with teachers of college physics. Many, as the result of bitter experience, have ceased to grant any credit to those who have studied physics in high school, placing all students on the same footing. That such a procedure is fair neither to the schools nor to the students is clearly shown in Figure 8. The average percentile rating on the 1935 tests of all students who had studied physics in school is graphed in the upper line; that for all students who had *not* previously studied physics in the lower line. The former group is consistently at or above the general average, while the latter group is consistently below. Thus it appears that the study of physics in school tends toward higher achievement in college physics; but whether it is the longer experience with college physics, or the selective influence of college physics following high-school physics, or both, cannot be resolved by these data.

Professional Goal.—When grouped according to the professional goal (Figure 9) we find that students in engineering rank higher in physics then those composing any other professional group. Doubtless we should have anticipated such a result, but we should have anticipated as well that the premedical group, who also need to apply their knowledge of physics directly to their professional studies, would have ranked higher. The indications of these graphs are irregular and clouded with uncertainties; but the differences seem to be great enough to suggest (1) the need for employing more reliable norms than are provided by these tests, (2) the advisability of adapting the content of our science courses more specifically to the actual needs of the different professional groups.

Correlation.—We should all greatly like to know how closely the post-test scores appear to be correlated with the pre-test scores, and also what correlation may exist between post-test scores and semester grades. Very little information has been published in the committee's reports on this point; but I have gathered a few data from private sources which I shall now present with some hesitation. My hesitancy is due to the fact that I am very doubtful as to the significance of the data. You must be the judge of that.

I am informed that the correlation coefficients between pre- and post-test scores on M and H combined at five colleges were as follows: 0.68, 0.77, 0.79, 0.80, and 0.81, with an average of over 0.75. These coefficients are rather high. They indicate that the pre-tests have more predictive and guidance value than could have been reasonably anticipated.

The committee's 1934 report cited six correlations between post-tests and semester grades. The coefficients ran from 0.66 to 0.88 with an average of 0.75, and they were followed by this comment, "It seems that the tests measure a function that physics teachers

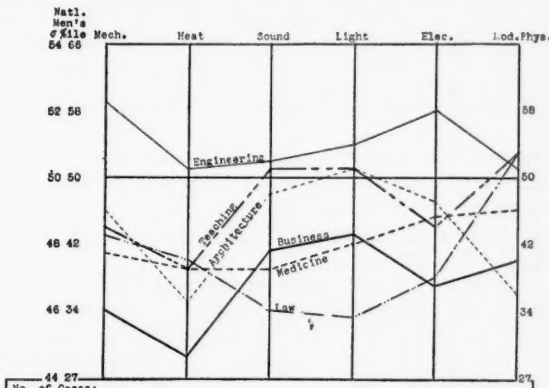

FIGURE 9.—PERCENTILE AVERAGES OF PROFESSIONAL GOAL GROUPS

consider important in their final grades, but they are not high enough to indicate mere duplication of grades."

One of my correspondents writes, "I have found in my own section a rather reasonable correlation between test grades and other grades. On the other hand, Prof.— and his assistants, who are in charge of a much larger group (in the same university), have not found the desired correlation." It would be of interest to

know on what basis this class was sectioned, and whether Prof.— is considered to be as good a teacher as my correspondent.

In Figure 10 we see both types of correlation shown on the same chart belonging to a class in a college for women. On each vertical line is recorded the total score achieved by one member of the class in M + H + S on pre-tests, post-tests, and class grades. In general the peaks and hollows in one graph correspond to those in another.

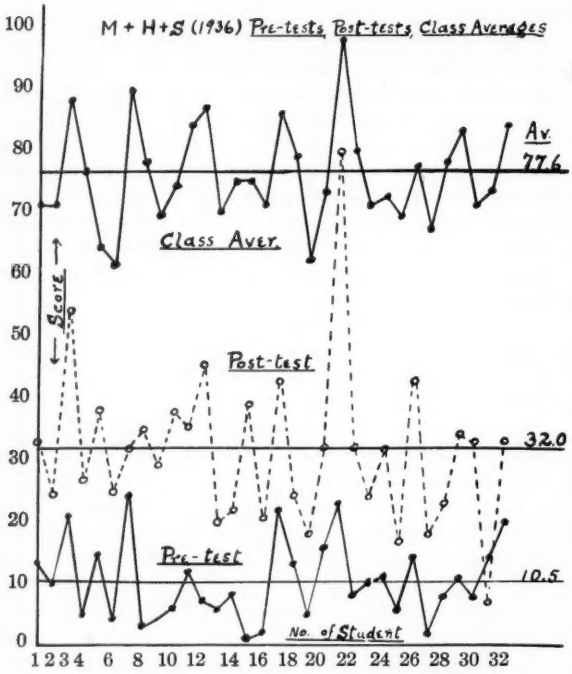

FIGURE 10.—INDIVIDUAL SCORES MADE BY MEMBERS OF A CLASS IN A COLLEGE FOR WOMEN

Comparison may be made between pre-tests, post-tests, and class averages. The students were numbered from 1 to 32

Figure 11 shows a similar study made of a class in a college for men with similar results.

Miscellaneous Uses.—I have already pointed out a variety of ways in which our objective tests in college physics are proving helpful and stimulating to teachers. To these I shall add without further discussion three ways in which the tests are proving to be useful at one of our large universities, namely, (1) in the placement of students transferring from another institution, (2) in the placement of graduate students and (3) in forming an estimate of the relative value of the instructors in the general physics course. Poor instructors! That for them the tests should have become such a boomerang was very far from the minds of the testing committee of the American Association of Physics Teachers.

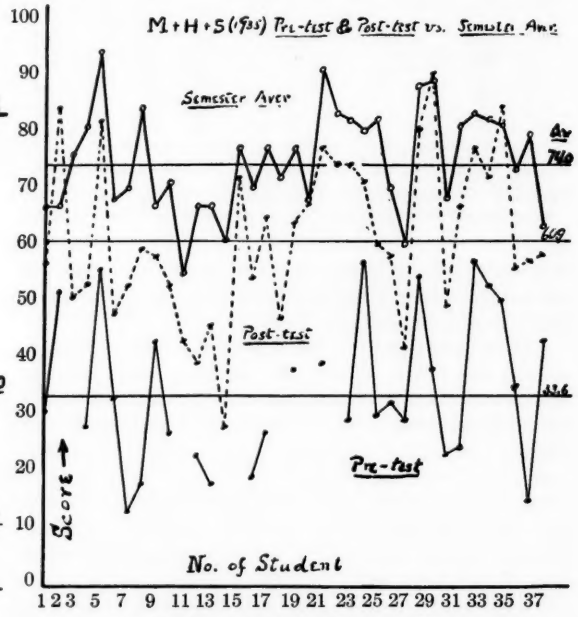

FIGURE 11.—INDIVIDUAL SCORES MADE BY MEMBERS OF A CLASS IN A COLLEGE FOR MEN

Comparison may be made between pre-tests, post-tests, and class averages. Each student was numbered from 1 to 37

FORRIS JEWETT MOORE LECTURES

The second series of Forris Jewett Moore Lectures under the auspices of the Chemistry Department of the Massachusetts Institute of Technology was given on February 17, 18, and 19, 1937, by Claude S. Hudson, Professor of Chemistry at the National Institute of Health, Washington, D. C., on the subject "Isomerism in the Carbohydrate Group."

The lecturer discussed the isomeric forms which the simple sugars are capable of assuming, described the experimental methods (some of which are new) for determining the structures and stereo-configurations of the isomers, and indicated the ways in which the union of these isomers give rise to the compound sugars, to starch, and to cellulose.

The Forris Jewett Moore Lectures are a part of the program of the Chemistry Department of the M. I. T. for heightening the interest of chemistry and making evident its cultural and humanistic relations.

The ORGANIC CONTENT *of* TWELVE HIGH-SCHOOL CHEMISTRY TEXTBOOKS

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THE Committee on Correlation of High-school with College Chemistry has recently published (*1*) a revised outline of essentials for a year of high-school chemistry. The recommended basic and additional material has been organized into eleven units, one of which deals with "Carbon, Carbon Dioxide, and Carbon Monoxide," and another with "Organic Chemistry."

The first of these units includes as basic material, the electronic structure, the occurrence, commercial preparation, and useful forms, and uses of carbon; the occurrence, preparation, properties, and uses of carbon dioxide; and the properties and poisoning by carbon monoxide. An additional topic includes the possible preparation of carbon monoxide as a teachers' demonstration. Two required laboratory experiments deal with the adsorptive and reducing powers of carbon, and the preparation of carbon dioxide and a study of its properties. Three possible optional experiments added deal with a study of baking powders, preparation and properties of carbon monoxide, and a study of oxidizing and reducing flames.

The other unit is entitled "Organic Chemistry." Basic material deals with the old and new definition of organic chemistry; composition; formula correspondence between inorganic and organic substances; structural formulas; and industrial sources of certain hydrocarbons and accompanying side products. Additional topics suggested for supplementary, but not necessarily required, study, cover in some detail the hydrocarbons, alcohols, organic acids, esters, carbohydrates, foods, and miscellaneous organic compounds such as soap, nitrogen compounds, formaldehyde, ether, and halogen derivatives of the hydrocarbons.

The Committee offers ten major objectives to aid the high-school teacher in developing the topics of the outline. The first is "To show the service of chemistry to the home, to health, to medicine, to agriculture, to industry; in a word, to show the service of chemistry to the country." While the study of organic chemistry may not lend itself so readily to the teaching of the general principles of chemistry, yet there is probably no branch of the science that offers greater opportunity for a study of its applications and future possibilities than work in organic chemistry. It was largely due to the author's vital interest in organic chemistry, his suspicion that this phase of high-school teaching is often neglected, and his desire to compare the organic content of several representative high-school chemistry texts with the recommendations of this committee, that led to this study.

A page-by-page examination was made of the following twelve widely used high-school chemistry textbooks. Each text in this list has been given an alphabetical designation which will be used in Table 1, to designate this same textbook.

(A) BLANCHARD, ARTHUR A. AND WADE, FRANK B., "Foundations of chemistry," American Book Co., New York City, **1914.**

(B) BRADBURY, ROBERT H., "A first book in chemistry," D. Appleton-Century Co., New York City, **1934.**

(C) BROWNLEE, RAYMOND, B., FULLER, ROBERT W., HANCOCK, WILLIAM J., AND WHITSIT, JESSE E., "Chemistry of common things," Allyn & Bacon, New York City, **1914.**

(D) BROWNLEE, RAYMOND B., FULLER, ROBERT W., HANCOCK, WILLIAM J., SOHON, MICHAEL D., AND WHITSIT, JESSE E., "First principles of chemistry," Allyn & Bacon, New York City, **1934.**

(E) DINSMORE, ERNEST L., "Chemistry for secondary schools," Laurel Book Co., New York City, **1931.**

(F) EMERY, FREDERICK B., DOWNEY, ELZY F., DAVIS, ROSCOE E., AND BOYNTON, CHARLES E., "Chemistry in everyday life," Lyons & Carnahan, New York City, **1928.**

(G) GRAY, CARL W., SANDIFUR, CLAUDE W., AND HANNA, HOWARD J., "Fundamentals of chemistry," Houghton Mifflin Co., New York City, **1934.**

(H) HESSLER, JOHN C., "The first year of chemistry," Benj. H. Sanborn & Co., New York City, **1931.**

(I) HOLMES, HARRY N. AND MATTERN, LOUIS W., "Elements of chemistry," The Macmillan Co., New York City, **1928.**

(J) IRWIN, FREDERICK C., RIVETT, BYRON J., AND TATLOCK, ORRETT, "Beginning chemistry and its uses," Row, Peterson & Co., Evanston, Illinois, **1927.**

(K) MCPHERSON, WILLIAM, HENDERSON, WILLIAM E., AND FOWLER, GEORGE W., "Chemistry for today," Ginn & Co., New York City, **1934.**

(L) VIVIAN, ALFRED, "Everyday chemistry," American Book Co.. New York City, **1926.**

A tabulation was made of the type and amount of organic material contained in each textbook. Considerable difficulty was experienced in arriving at conclusions in many cases. The line of demarcation between inorganic and organic material is not always distinct and definite. For example, the subjects of oxygen and fuels are frequently so intimately interwoven that it is almost impossible to evaluate properly the proportion of space to be logically credited to each

subject. The author has also preferred not to include all references to all carbon compounds as organic in nature. Such a procedure would necessarily result in the inclusion of all pages devoted to limestone, hardness in water, siderite, and similar topics. And so the line of distinction was drawn rather arbitrarily to include as organic material only those references to carbon, the carbonates, carbides, and similar topics that seemed to have a rather definite connection, either expressed or definitely implied, with the usual topics included in typical organic texts. For example, the only references to carbonates included under that heading are those that deal with their use as a leavening agent and similar uses, at least semiorganic in nature. Some might question the inclusion of topics dealing with carbon, diamonds, graphite and coal, and yet the space devoted to these topics is relatively small and uniform in amount, ranging from six to twenty-four pages. Thus any error introduced because of this practice is relatively small and nearly constant in comparison to total results. The same can be said for the space included under carbon dioxide, carbon monoxide, carbonates, carbides, carbon disulfide, etc. Those who might prefer to omit these topics from a tabulation of this kind can easily arrive at the corresponding new values by a study of the information given in Table 1. However, no great changes would result in the positions of the texts studied. Percentages would be lower, but in approximately the same order, since these items run as nearly constant as most of the topics listed in the tabulation. After all tabulations were completed, the figures were rounded off to the nearest whole page since no study of this type can hope to maintain a consistent precision greater than that. The results of the study are tabulated in Table 1.

TABLE 1

PAGES OF ORGANIC MATERIAL IN TWELVE HIGH-SCHOOL CHEMISTRY TEXTBOOKS

Textbook Designated by	L	F	C	G	K	I	E	J	B	D	A	H	*Total*	*Avg.*	*Mean*
Carbon, Diamond, Coal, Graphite, etc.	12	21	13	12	23	24	19	12	19	21	6	12	194	16.2	13
CO_2, CO, Carbonates, Carbides, CS_2, etc.	20	16	47	15	20	16	32	21	25	33	30	13	288	24.0	20
Hydrocarbons	6	15	39	27	16	11	15	17	20	22	9	10	207	17.3	15
Alcohols, Ethers	5	3	9	3	7	4	6	5	6	4	3	2	57	4.8	4
Organic Acids	6	3	3	1	3	1	4	2	2	3	2	1	31	2.6	2
Aldehydes and Ketones	1	1	3	1		2	1	2	1	3		1	16	1.3	1
Esters	1	4	6	2		1	1	6	1	2		1	25	2.1	1
Carbohydrates	12	33	13	14	16	13	11	13	13	9	4	7	158	13.2	13
Fats and Soaps	11	18	14	10	8	3	6		5	4	2	6	87	7.3	6
Proteins	11	14	6	7					5		1	1	45	3.8	1
Foods and Digestion	66	38	51	21	9	12	11	14	1		2	5	230	19.2	11
Plants and Soils	157	22	26	11	10	9	2	15	2	6	5	4	259	21.6	9
Miscellaneous, Experiments, etc.	20	109	20	16	9	7	7	5	9	11	1	3	217	18.1	9
Total Organic Pages	328	297	250	140	121	103	115	112	109	118	65	66	1824	152.0	115
Total Pages	560	719	616	650	588	519	585	607	633	777	446	580	7280	606.1	588
% Organic Material	58.6	41.3	40.6	21.5	20.6	19.8	19.7	18.5	17.2	15.2	14.6	11.4		25.1	19.8

An examination of the data in Table 1 shows that the number of pages devoted to organic material, as classified in this study, varies from 65 to 328 pages, or from 11.4 to 58.6 per cent., in the twelve representative high-school chemistry texts. The average number of pages is 152 and the mean is 115. However, it should be mentioned that the first three texts included in this tabulation have been written for special purposes, and the high organic content of these texts has noticeably affected certain totals.

Vivian's "Everyday chemistry," for example, is divided into three parts. The first deals with the usual inorganic and theoretical items, the second with organic and applied chemistry, and the third with soils and fertilizers. Pages 244 to the end of the text are devoted to the last two parts. The author states that the purpose of the ordinary high-school course in chemistry in the past has consisted of a condensed treatment of the subject of inorganic chemistry, which was intended to prepare for the further study of that subject in college. In this volume theoretical items have been selected which would lead to a later understanding of daily life, or were necessary for the explanation of some other fact or theory that is essential to an understanding of daily life. It is largely this point of view of the author that has led to the high (58.6) percentage of organic material in this text.

"Chemistry in Everyday Life," by Emery, *et al.*, offers an unusually wide range of material, thus producing a text somewhat larger than the average elementary chemistry. The first 393 pages cover the usual college requirements, and the remaining pages, largely organic in nature, are based upon topics suggested by many teachers of chemistry throughout the United States. Besides a treatment of the usual organic topics, special chapters are devoted to Paints, Oils, Varnishes; Leather and Tanning; Sanitation; Medicines and Patent Medicines; Chemistry in War and Peace; Poisons, Tobacco, Alkaloids, and Glucosides; and similar topics. Naturally, the inclusion of large quantities of material of this type has greatly affected the total number of pages of organic material in this particular text.

The "Chemistry of Common Things," by Brownlee, *et al.*, as the title indicates, deals with the chemistry of everyday affairs. The first 159 pages deal with the fundamental ideas and principles. The second part supplies material for courses adapted to special needs and puts the chemistry of common life into a form at once attractive and useful. Naturally, the percentage of organic material in this second part is relatively high and noticeably affects the final percentage of 40.6.

But aside from this special type of material in these three texts, the number of pages devoted to the usual organic topics is surprisingly uniform. Cornog and Colbert (*2*) in a previous study have analyzed the content of high-school and college chemistry texts but make no statement concerning the organic content. Bothe (*3*) reports a lower organic content on two of the texts included in this study than was found in this investigation, but this may be due to the fact that a large portion of organic material was undoubtedly included in his everyday, industrial, and commercial applications.

The subjects of carbon dioxide, carbon monoxide, carbonates, carbides, etc., which at best are only semi-organic in nature, seem to claim first place in importance. The subject of plants and soils occupies second rank, but this is mainly due to the influence of the textbook by Vivian. Information dealing with foods and digestion runs a close third. Next, or first place among the strictly organic topics, goes to hydrocarbons, and this is largely due to the emphasis placed upon petroleum, natural gas, and their commercial products. Other topics in order include carbon and its allotropic forms; carbohydrates; fats and soaps; alcohols and ether; proteins; organic acids; esters; and finally aldehydes and ketones.

The author was surprised to find some texts devoting so little attention to the subjects of proteins, and foods and digestion. The subjects of aldehydes, esters, and ketones are completely omitted or discussed very briefly in several instances, although all but ketones are included in the recent, "Outline of Essentials for a Year of High-school Chemistry" (*1*).

CONCLUSIONS

The results of this study indicate that:

1. There is a wide variation, and yet a surprisingly consistent coverage, of the usual organic topics in these twelve representative high-school chemistry textbooks.
2. Textbooks that are designed for special applied courses, or to meet special vocational needs, usually contain a higher percentage of organic material than books designed for regular class use.
3. The subjects of proteins, esters, aldehydes, and ketones seem to command least attention.
4. Aliphatic topics receive far more space and attention than aromatic topics.
5. The basic and additional topics for an "Outline of Essentials for a Year of High-school Chemistry" are well covered in practically all the twelve textbooks studied. If high-school instructors follow and teach the material contained in these twelve high-school chemistry textbooks, they can easily meet the requirements of this standard course in chemistry.

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The STUDENTS' COURSES *at the* CHEMICAL EXPOSITION

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THE seven Students' Courses which have been held in connection with the Exposition of Chemical Industries have been of great benefit to several thousand students, and have represented an interesting experiment in chemical education.

The first three courses were held in late September, when colleges either had not opened or were just beginning their fall terms. The student attendance at first was not large, from one hundred fifteen to one hundred sixty-five, but most students spent from four to six days at the Exposition. In 1929 the date of the Exposition was changed to May and in 1933 to early December. Due to the change in date the attendance at the 1929 course fell off somewhat. The whole plan was then altered to provide for a shorter period of attendance. In 1931 over two thousand students were

registered as having visited the Exposition, and about five hundred attended one or more of the lecture sessions during the week. In 1933 the total number of students who filled out registration cards was over three thousand and the estimated number attending lectures was around nine hundred.

An analysis of the 1931 and 1933 groups indicated that too large a proportion were unprepared to profit by what they saw and heard. Accordingly, in extending invitations to colleges for the 1935 course, the request was made that only those students be sent who could really get the most out of what was offered. No record was kept of those students in the metropolitan area who came on exhibitors' invitations "just to look around for an hour or so," and who were not actually using the Exposition as a definite part of their training. The total number of students registered at the 1935 course was seven hundred fifty. Of these about five hundred attended one or more lectures. Several large groups from out of town could spend only a limited amount of time at the Exposition and confined their activities to studying exhibits.

In the first four courses, when students could spend the larger part of the week, an effort was made to cover all the more important unit chemical engineering operations and materials of construction. There were several short talks each day. In the course of a week a student received a fairly comprehensive survey of the field of chemical engineering. The earlier courses were divided into an elementary and an advanced group for a part of each morning, with simultaneous programs. With the shortening of the time that students could remain at the Exposition, the lectures became more general in their nature and were of equal interest to chemists and chemical engineers. The programs of the last three courses have appeared in the JOURNAL OF CHEMICAL EDUCATION (*1*).

In the 1935 course the morning lectures, three each day for five days, dealt with chemical economics; the problems of the individual in the profession; and with recent research, engineering, and industrial developments. In order to cover the new things shown at the Exposition, there were four afternoon conferences conducted by teachers of chemical engineering. For the benefit of groups of students without previous training in chemical engineering or industrial chemistry, an introductory lecture was given on the opening day and repeated three times thereafter on "The Exposition, What to See and How to See it." Those who attended these lectures were furnished with a set of questions which guaranteed that no important part of the Exposition would be missed. On the closing afternoon there was a special program for women students of chemistry, sponsored by a committee of women teachers and consultants.

An analysis of the attendance of students at the 1935 Exposition shows that one hundred fifty individuals from six schools heard the introductory lectures, and two hundred ten other students from fourteen schools were present at the morning lectures. Ten students attended more than two mornings, and one hundred seventy came only one morning. The total attendance at the women's meeting was sixty, about half of whom were students. Eight institutions were represented by substantial groups in the afternoon conferences; of these only one group came consistently to all of the sessions. A total of one hundred fifty individuals were present, and of these, ninety attended only one conference. Few of these students came to the morning lectures, and few who attended in the morning came also in the afternoon. On the whole about five hundred different individuals were present at one or more of the fourteen sessions held during the week, and of these four hundred came only once. There were fully one hundred fifty students at the Exposition in groups led by their instructors, who attended no lectures, but who did a thorough job of studying the exhibits. Another one hundred represented individuals who did much the same thing without direct supervision.

The afternoon conferences were made up almost entirely of chemical engineering students in the metropolitan area; but at the morning lectures more than eighty per cent. were from institutions outside of New York, and these groups contained fewer chemical engineers. The total number registered was rather evenly divided between those in chemistry and in chemical engineering courses. Each of the three large groups that did not attend lectures came from fifty to two hundred miles to visit the Exposition. With the exception of these groups, most students came from within one hundred miles of New York City.

Since the beginning of these courses in 1923, more than one hundred fifty men have talked to student groups. In practically all cases the speakers have been leaders in their own field and specialty, and the proportion of men known to the entire profession has been exceptionally high. The student groups at each session during the seven courses have varied from thirty to two hundred. Probably as many as two thousand different students have actually put in from several hours to the better part of a week in using the Exposition as a definite part of their training. More than fifty different institutions have been represented at these courses. Most of the students were juniors, seniors, and graduate students preparing to make chemistry or chemical engineering their life work. A few high-school teachers have attended each year, but even when special programs have been given for them, the number attending has been low.

That the Exposition has something worth while to offer to students is proved by the number of colleges taking advantage of this opportunity, and by the number of students from these colleges. While many things a plant trip has to offer cannot be duplicated at the Exposition, there are many things that can be seen and understood much better by viewing a large collection of exhibits (*2*). The more a student knows about chemical engineering operations, equipment,

and materials, the more information he derives from study at the Exposition. At the same time, a student who knows little about chemical engineering and applied chemistry is greatly benefited by discovering the wealth and variety of things with which chemical industry is concerned. Beyond the matter of information, there is the intangible but very real attainment of a new vision which many students have accounted the most valuable thing that the Exposition has given them. The morning lectures have become less technical and specialized, and are now almost entirely devoted to ideas which students do not get in any of their college courses.

So far nothing has been said about the attitude of the exhibitors, and after all the Exposition is supported by exhibitors and run largely for their benefit. In the earlier years of the Exposition, in addition to the invited guests of exhibitors, the general public were privileged to buy tickets and attend. For several years past, however, attendance has been restricted to those within the industries served, and all who attend have registered with details of their occupations. Thus, students are guests admitted to an exposition that is primarily arranged for technical, professional, and business men. There are some exhibitors who regard students as a nuisance. They think of them as boisterous, ill-mannered, and inconsiderate youngsters, who collect booklets that they can never use, and interrupt conferences with their best customers. The strict limitation on invitations to colleges and the repeated warnings given at lectures have largely eliminated this type of student. It should be noted here that high-school students are not admitted, and only mature and serious students majoring in chemical subjects are welcomed. The majority of exhibitors, particularly those who have been represented at practically all of the fifteen Expositions, approve of the admission of a limited number of properly qualified students to the Exposition. Some of them say that students of the earlier courses are now appearing on their lists of customers and clients. Since the principal purpose of the Exposition is to interest and educate those who will buy the wares of the exhibitors, it is entirely fair and just that the exhibitors should demand that only those students be allowed to attend who are really interested, who will take their visits seriously, and who will show their appreciation by courteous and considerate conduct. While a great many students in chemistry courses who are not majoring in the subject would find a visit to the Exposition interesting, and probably would not abuse the privilege of an invitation, they would cause such crowding that the exhibitors would be entirely justified in asking that they be excluded. Consequently, the exhibitors should agree on a policy of limiting invitations to students and live up to it. All tickets of admission should be sent by the Educational Division and not by individual exhibitors.

In fairness to the exhibitors and to the students, each college should be represented by one or more members of the instructional staff responsible for the guidance and care of their own students. Those students who have had no previous training in the fields covered by the Exposition should attend the introductory lecture and receive a set of questions that would insure thorough study of the exhibits. The morning lectures are of particular value to out-of-town students who wish to spend one or more full days in New York. The attendance during the past course was satisfactory on the first day and the last two days, but dropped off during the middle of the week. Colleges should register their students sufficiently early so that speakers may be invited for those days when a satisfactory group of not less than fifty students could be counted on. The afternoon conferences on the new things at the Exposition were intended to cover the entire field in four sessions, yet the majority of students attended only one session. Either a sufficient number of institutions should agree to combine their groups and have their students attend all the sessions, or there should be a single session in which only the most important developments are discussed; this should be repeated as often as necessary. Whatever arrangements are made for conferences and lectures, there should be a very definite schedule for each group to visit the exhibits. A study of general attendance figures shows that the first three hours after the Exposition opens, that is twelve o'clock until three, are the best hours for student groups.

After more than twelve years of experiments covering seven different Expositions, the educational program should become less impromptu and more thoroughly systematized and standardized. While a great deal of assistance has been given by individuals in the way of advice, and still more by the giving of carefully prepared lectures, the actual supervision of the courses has been in the hands of the general chairman, with the liberal assistance of the Exposition management. With the exception of one good-sized gift, all expenses have been borne by the Exposition company. In the 1935 course, a committee of teachers of chemical engineering, headed by Dr. H. J. Masson of New York University, were invited to conduct the afternoon conferences. In order to insure permanence and better handling of this educational work, there should be a regular organization to collaborate with the management, to be made up of representatives of the schools and colleges that wish to use the Exposition for instructional purposes. This organization should plan the program, invite speakers, determine the number and qualification of students to be admitted, and have general charge of the students' courses.

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WHITHER CHEMISTS*

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"To a job we love we rise betime
And go to it with delight."

I HOLD a very warm spot in my heart for Haverford College. It was upon this campus that the late Professor Theodore William Richards—a man whose memory I revere—received his early training in chemistry. Harvard and the world owe a deep debt of gratitude to Haverford for the training and inspiration which Professor Richards received in this scholarly environment. The life and works of this great Nobel Laureate have been, for me, inexhaustible sources of guidance and hope, and they should also provide the example and stimulus for all Haverford men, especially for those who have chosen chemistry as their specialization.

A quarter of a century ago, it was my good fortune to study under Professor Richards. In a conference with this universally recognized scholar and teacher, I expressed a desire to enter the teaching profession. In his usual gracious manner he informed me that the financial outlook in teaching was not as promising as that of business; that if I entered the profession of teaching I need not expect to own a mansion, works of art, a valuable private library, or even an automobile—automobiles were much more expensive then than they are now. "However," he counseled, "teaching will make possible the continuance of your investigations with freedom and the opportunity to inspire others in the study of chemistry and in the building of character."

The advice which he gave me rings as true today as it did twenty-five years ago.

Half a century has passed since Professor Richards set out from Haverford for Harvard to begin his graduate studies. At this moment a curious reflection is passing through my mind. Am I facing a young man today who will, in the course of time, leave to science and the world original contributions to the store of human knowledge equal to those of the man who, at the tender age of seventeen—the very springtime of life—received his A.B. from Haverford. This I do know. You are interested in "Whither Chemists?" because all of you, after devoting your lives thus far to acquiring information and to being trained in the profound science of chemistry, will soon be turning to industry or teaching to test in practice the knowledge and training you have acquired. You will presently assume the responsibility of contributing to the advancement of chemistry. And you are asking yourselves in "Whither Chemists?" what this responsibility really is and how well you can bear it. Let us see.

I consider you students of the colleges of Eastern Pennsylvania a select group. Perhaps you do not realize just how select you are. You have weathered grade school and high school, and your scholastic records in high school were of such worth that you were considered suitable material for admission to college. Statistics, if I may be permitted to stand on that treacherous ground, show that only fifty per cent. of the children who enter the first grade complete grade school; fifty per cent. of the young people who graduate from grade school complete high school; thirty-five per cent. of the high-school graduates matriculate in college; and sixty-five per cent. of those who enter college complete the work necessary for graduation. It must be apparent that your comparative educational status has been greatly improved during the past fifteen years. You have gone ahead, while ninety-five per cent. of those who started with you have been compelled to take less favored courses. Because of your gifts and good fortune, your responsibility to the science of chemistry and to humanity has been increased in like proportion—even beyond that, to a degree that you cannot now fully realize.

I believe, however, that you should realize this responsibility in part. No doubt you do, for a portion of it is scholarship, and you certainly must know its significance. Scholarship is very essential to success, for it gives evidence of the interest and capabilities of the student. Contrary to popular opinion, based on rare exceptions, a student who excels in scholarship is more apt to be successful in later life than one who does not take scholarship seriously. "Everyone, doubtless, knows a few brilliantly successful individuals who, as college students, were habitually on the ragged edge of dismissal, and who finally squeezed out a diploma more or less through sufferance of their professors. Conversely, some cases lead us to believe that brilliant students are more than likely to fail in the arena of practical life. However, a two-year research by Hugh A. Smith into the records of 1800 men who graduated from the University of Wisconsin between 1890 and 1920 appears to explode these views convincingly. His findings show an agreement as to degree of success in college studies and in subsequent worldly activities that is almost unbelievable. Perhaps the most striking thing revealed is this: from the 1800 men, 95 were selected as having become 'the most worthy, successful or eminent.' Another list was prepared of the 95 who as students had attained the highest average grades. On comparison, it was found that 87 men were on

* Given at Haverford College, Haverford, Pennsylvania, April 18, 1936.

both lists! With respect to engineers, one may be inclined to think that the correspondence between college success and future success is probably greater than in business or in most other professions. In any event, the facts revealed by Dr. Smith should be a source of comfort to science and engineering students who, on occasion, may feel that their studies are a bit too arduous, and that good marks are not indispensable to later success."

My past experience tells me that you students may be divided into three classes. First are those who have decided on the work in chemistry they want to do. They have known from the first what they wanted and where their opportunities lay. Perhaps they were previously in industry, realized their limitations, corrected them in college, and are now going back. Let me illustrate. A senior at Carnegie knew what he wanted; he had his heart set on a job with du Pont. After some negotiations, he received a wire asking him to report for an interview in Wilmington. It was at the beginning of the Pittsburgh flood, and he telephoned me apologetically at midnight for advice. Trains were not running, but he said that by taking a plane to New York, he could reach Wilmington in time for the appointment. When I said, "Go," he replied, "That is what I wanted you to say." He made the trip, and the interview was successful. He begins work on July 1 as an explosives chemist. I know that there are students present, though few in number, who, like him, have their hearts set on a particular job.

To the second class belong those who have been assigned to the study of chemistry. They are the sons of explosives, dye, perfume, soap, food, or rubber manufacturers; their positions are awaiting them. They are preparing to replace a parent or a chemical director. These students are fortunate, but few.

The third class is composed of those who are in doubt as to the type of chemical work they wish to undertake. I appreciate the difficult position of a senior when he is fortunate or unfortunate enough to receive several offers from industrial concerns as a result of interviews. A few days ago I was consulted by a senior who was struggling to make a decision between two positions, one in the rubber industry, the other in the oil industry. Because of my long experience in rubber he felt that I was responsible for his offer from the Goodrich Rubber Company and that he was obligated in some indefinite way to me. I soon corrected that misapprehension. I am always wary of telling anyone what he should do, especially a senior. Accepting an obligation or a responsibility is an individual problem. At the same time, while I am making this statement, I realize that a straightforward request for advice should have a straightforward answer.

Despite my classification of these three groups, I still wish to speak to all of you—to answer your straightforward question "Whither Chemists?" Chemistry offers excellent opportunities in two large fields of endeavor, the teaching of chemistry, and the application of chemistry in industry. Even now it is difficult for most of you to reach a decision as to whether your opportunities lie in teaching or in industry, whether your inclinations, aptitudes, and training best fit you for one activity or for the other. In order to make the decision seem less difficult, let us examine some of the easier aspects of the situation. My opinion is that students with a four-year college training in chemistry are qualified to make a living in laboratory positions in industry. But what is that? They are, in the jargon of the profession, "lab dogs." They should be warned that in industry they will meet keen competition from chemical engineers whose training has been pointed toward unit operations, rather than chemical analysis and fundamental research. On the other hand, students who have had the necessary courses in educational subjects can undertake the secondary-school teaching of chemistry. For those of you who have excelled in scholarship and desire to enter research or college teaching, I strongly recommend that you continue your studies in a graduate school under a professor whose field of investigation especially appeals to you and who has a reputation for inspiring those who study under his direction. Graduate work is open to men of exceptional promise, and it certainly has its lure. The problem of financing graduate study is quite as difficult as making up your mind to do graduate study. In all of our universities, scholarships, fellowships, and teaching assistantships are open to those of unusual scholastic attainments and special aptitudes fitting them for graduate study. Those of you who have not excelled scholastically are not granted this opportunity. It would be well, too, for these latter students to weigh carefully the advisability of undertaking graduate work, even though they have financial support upon which to rely. The reason I am urging caution is that mediocre scholarship is often the result of the lack of interest, or of the dispersion of energy. Any student who is not definitely determined upon his future course or his future interest would do well to settle upon what it is to be before putting further time and money into a makeshift. The question for such a youth is not so much "Whither Chemists?" as it is "Whither Student?"

Let me return to our discussion of graduate study. There is considerable impatience among young men who are graduating from college. They are anxious to go to work, to do something productive, and it is difficult for them to see the desirability of continuing their studies. To young men of promise who have the financial backing, I usually tell the story of the training and experience of one of my close personal friends, Dr. E. K. Bolton, who devoted many years of his life to the acquisition of an education before he entered industry. After four years of undergraduate work at Bucknell University, he spent five years in graduate study at Harvard before he obtained a Ph.D. degree. It takes courage, stamina, perseverance, and foresight to devote so much additional time to graduate study in preparation for a hoped-for position of which, seemingly, there is no assurance. After he obtained a Ph.D., Dr. Bolton was awarded an Austin Travelling Fellow-

ship and spent two additional years in Germany, studying under Willstätter. Within the first six weeks, he had isolated and determined the constitution of the red coloring matter in geraniums. When he returned to the United States, he was offered an instructorship in chemistry, which he declined in order to accept a position as chemist with the du Pont Company. A dozen years later we find him Director of Research of this mammoth organization.

Another friend of mine, Dr. Roger Adams, received his early training in chemistry, pursued graduate work, studied abroad, and returned to become an instructor in organic chemistry at Harvard. He accepted a position with the University of Illinois. During the whole period of our friendship, I have marveled at the enthusiasm he has displayed toward the science of chemistry. During our college days he was ever talking chemical reactions, whether we were in a study room, on a hike, or attending a "pop" concert. In the "war to end all wars," he was a major in the Chemical Warfare Service and was responsible for "Adamsite," a sneeze gas. After the war he was advanced to the chairmanship of the department of chemistry at the University of Illinois. He has numerous contributions to his credit. As a result of his exceptional ability in chemistry, he will be awarded the Willard Gibbs Medal in May of this year. He is a past president of the American Chemical Society and a Nichols medalist.

I like to tell of a young man who was studying chemistry at Harvard University when I was a student there. As a senior he had started research work in organic chemistry under Professor Elmer Peter Kohler. He graduated with honors and was awarded a Phi Beta Kappa Key. His research work was in organic chemistry. After he received his Ph.D. degree, he worked in a chemical plant for one year. He then returned to Harvard as an instructor and was rapidly advanced in rank to assistant professor, associate professor, full professor, and ultimately chairman of the department of chemistry. When President Lowell retired, James Bryant Conant was selected for the presidency of the oldest American university.

While I was teaching at the University of Montana, a very able student solicited my advice as to whether he should specialize in physics or in chemistry. I suggested that he familiarize himself with both and devote his attention to the borderline problems. He pursued graduate work at the University of California, accepted an instructorship at Johns Hopkins University, and was later called to Columbia University. Seventeen years after he received his degree from the University of Montana, he was awarded the Nobel Prize for the discovery of "heavy water." Harold Urey's name is familiar to all of you.

You may think that these men are the exceptions; that they possess unusual qualifications, even genius; or that they are unusually lucky. It is my opinion that this is not quite the case. As students, they showed no more promise than many a student who faces me. What is more, the progress of science has given you equal or better opportunities than they had. What do my illustrations mean? They signify that chemists of promise who desire to enter chemical research, or any other field of research, should not be content with a four-year undergraduate course. The broader the undergraduate course and the better the graduate training, the more probable is a man's success in research. Let me give you one example of the necessity for extensive preparation in research. In the rubber industry, the determination of the constitution of the rubber molecule, the preparation of synthetic plastics, the discovery of new adhesives, the economical selection and preparation of new materials for the vulcanization, acceleration, preservation, reinforcement, and loading of rubber, and the finding of new uses for a material that already is utilized in making more than thirty-five thousand different products, present problems which are a challenge to the best trained and most ingenious minds. Is it not apparent that the better you are prepared, the better are your chances of succeeding?

Now, what about industry? What opportunities is it providing? With the return of better business, all of our institutions of higher learning are being visited by industrial scouts. Industry is searching for men of scholarship and training who are qualified to work in such fields as rubber, dye manufacture, heavy chemicals, explosives, pigments, resins, organic chemicals, sugar, paints, fuels, foods, and the like. Many training schools have been developed for the chemists and chemical engineers who are carefully selected from preferred colleges and universities—special recognition being invariably given to students doing graduate work. It is the policy of the companies to select the better trained men from a large number of widely scattered institutions in order to avoid clannishness, to stimulate competition, and to profit from whatever differences there are in educational trends. Recent graduates are not usually required to have experience in the specific industry's technology. During a preliminary training period in any given plant, the college and university graduates are given manual work in the various production departments in order to become acquainted with production operations, methods, and costs. The men are supplied with handbooks, and time is set aside for talks by experienced men on the properties and uses of materials, physical testing, compounding, construction, materials control, engineering problems, costs, time study, sales, and research. When they return to the laboratory after this practical experience, they are better able to apply their chemical training to plant problems and, later, to select more intelligently the type of work that they wish to do. As for coöperation, I know, to use an example from one industry, that the rubber companies have a generous attitude toward research, and a very friendly spirit exists among the many research workers of rival companies. The chemists and chemical engineers have not confined themselves to tech-

nical work alone but have branched out into every phase of this major industry. The presidents of two of the four large rubber companies are men who were trained in chemistry.

It has been interesting to observe the change in attitude of industry toward the chemist in recent years. In the depression of 1921 the first department to suffer in many industries was chemical research. The drastic curtailment of research at that time showed a short-sighted policy and ultimately resulted in almost irreparable economic losses. During the period from 1930 until 1936, management, as a rule, showed more consideration for technical men and made an effort to preserve research organizations. Management has come to the realization that research organizations are not built up in a day, that years are needed to select and train technical men, that research requires careful nurture, and that complete abandonment of research programs with the dismissal of highly trained men, on the plea of financial necessity, is provocative of economic waste and is one of the surest ways to economic oblivion. On the other side, research men of ability are wary of affiliating with a company which has an unstable research policy and which deals in wholesale slaughter of personnel during dark days of economic stress. Every one is familiar with the fact that the chemical industries have withstood the depression very well. One of the primary reasons for this favorable outcome is the attitude of the industries toward, and financial support of, research. Chemical industries are now reaping their reward from a long-time investment in a department often unintelligently characterized as unproductive. You may be sure that industry will be ready for you when you are fully prepared.

I say "fully" advisedly, and I mean that while you are getting ready for your life's work, you should not neglect getting ready for life—to live. It would be unfortunate if your education were narrow—confined to specialization in one study—instead of being broad and liberal—embracing a variety of studies. The educational program in liberal arts permits of considerably more flexibility than that in the professional courses, such as engineering, medicine, and law. The Engineers' Council for Professional Development is devoting considerable attention to a survey of engineering colleges. If you examine the curricula in any of our engineering colleges, you will find that very little opportunity is afforded the engineering student to select elective courses in which he has a healthy and consuming interest. I raise the question, "Should the course in chemistry be so standardized that little opportunity is left for a student of chemistry to select subjects of his own choosing?" My opinion is that a young man who studies chemistry, in addition to a broad training in his chosen field, should supplement the work with a thorough grounding in mathematics, physics, and English. The scientific literature of the present day gives evidence that the papers which are being published in our chemical journals involve, in their preparation, the use and clear understanding of mathematics and physics. And may I say in passing that no student can consider himself well informed in his chosen sphere of study unless he is familiar with the current happenings in it. In brief, he should read the technical journals. May I say further that for a full joy of living, such subjects as history, languages, economics, sociology, psychology, astronomy, biology, and philosophy are essential? How many of you men have had the good fortune to study all of the subjects that I have enumerated? I do not mean exhaustively, but at least with sufficient training to have your cultural outlook liberalized. Robert Louis Stevenson, in "An Apology for Idlers," has anathematized the product of the narrow and limited education of which I speak.

"There is a sort of dead-alive, hackneyed people about, who are scarcely conscious of living except in the exercise of some conventional occupation. Bring these fellows into the country, or set them aboard ship, and you will see how they pine for their desk or their study. They have no curiosity; they cannot give themselves over to random provocations; they do not take pleasure in the exercise of their faculties for its own sake; and unless Necessity lays about them with a stick, they will even stand still. It is no good speaking to such folk; they cannot be idle, their nature is not generous enough; and they pass those hours in a sort of coma, which are not dedicated to furious moiling in the goldmill. When they do not require to go to the office, when they are not hungry and have no mind to drink, the whole breathing world is a blank to them. If they have to wait an hour or so for a train, they fall into a stupid trance with their eyes open. To see them, you would suppose there was nothing to look at and no one to speak with; you would imagine they were paralyzed or alienated; and yet very possibly they are hard workers in their own way, and have good eyesight for a flaw in a deed or a turn of the market. They have been to school and college, but all the time they had their eye on the medal; they have gone about in the world and mixed with clever people, but all the time they were thinking of their own affairs. As if a man's soul were not too small to begin with, they have dwarfed and narrowed theirs by a life of all work and no play; until here they are at forty, with a listless attention, a mind vacant of all material of amusement, and not one thought to rub against another, while they wait for the train."

While endeavoring to liberalize your culture, you should take care not to undertake an aimless mastery of all knowledge. Your efforts should be productive, creative. Knowledge has been expanded by such leaps and bounds that it is impossible for a man to make, like Francis Bacon, "all knowledge his province." I am reminded of an incident emanating from the apocrypha of President Eliot of Harvard. One evening in his study, he picked up a Harvard catalog. After a cursory survey, he discovered, to his surprise, that if he were to spend sufficient time to take all the courses

offered at Harvard, it would require one hundred eight years. Another story that I heard from President Eliot's lips is apropos of this discussion. He said that when Ralph Waldo Emerson was attending Harvard College, he took ninety per cent. of the work that Emerson wanted to take and ten per cent. of the work that Harvard wanted him to take. Apparently Emerson could not be content with mere indoctrination from above. He must follow his bent and explore some unknown. He must try his own creative impulses in some unmapped intellectual realm. Why? Because the experience is so convincingly satisfying. The qualification that pays the biggest dividend, whether it is in philosophy, science, law, or religion, is creative thought.

For you young chemists, I have been painting the pictures of opportunities that you will see in your quest for success. Before I leave, may I offer you a few words of homely advice, based on experience? When you enter a new community, associate yourselves with some church activity. It will thwart homesickness and enable you to form friendships that will be valuable to you in your social advancement. Purchase a life insurance policy, which will start you on the road to saving and assure those who have helped you of a return in case of misfortune. Attend all chemical meetings within the range of your pocketbook. Read the chemical literature in the field that you have chosen and as much more in fields of general culture as your time will permit. Cultivate the acquaintance and friendship of people who "have done things." Consciously strive to be individuals of character, breadth of interest, leadership, creative ability, and good companionship.

Thus far I have been discussing with you the materialistic phases of "Whither Chemists." There is a more important aspect—the spiritual—that we should not lose sight of in our quest for knowledge in our chosen science. There is a tendency for men of science to become so deeply engrossed in their work that they neglect to give the necessary attention to the care of their spiritual growth and development. The teachings of the great Master in no way conflict with the knowledge of chemistry that I have acquired. As a matter of fact, the deeper I delve into science, the clearer is my understanding of God, His teachings, and His universe. It is my opinion that those who contribute to an advance in the science of chemistry are unfolding—and they should unfold—the inexhaustible complexities of the universe and are thus contributing to the revelation of the greatness of God to their fellow men. Should not our ambitions as chemists be to discover the hidden truths, with the objective in mind of benefiting not only mankind, but also ourselves, both materially and spiritually? Thus,

"New occasions teach new duties; time makes
ancient good uncouth;
They must upward still, and onward, who would
keep abreast of Truth."

CHEMISTRY *in* GERMAN SECONDARY SCHOOLS*

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FOR the past several years our teachers have been examining American education most critically. Many revolutionary breaks have been made with our traditional system, not only in theory but in practice. In defense of some of these breaks we have had various European ideas held before our eyes. To me it has appeared all too often that the same examples were used to substantiate opposite claims. This was especially true in the collegiate field.

My interest has been in chemical education at the college level, and not being too greatly displeased with the results being obtained by the old scheme of things, at least in so far as my own field was concerned, I have taken a position more or less in defense of the status quo. The controversies brought several questions to my mind which the conflicting statements of advocates of various schemes only tended to confuse. Let me state a few of these questions.

Is it possible to build a European university education on an American secondary education without suffering a loss?

If possible, is it feasible to modify our high schools so as to build toward a European superstructure?

Are there inherent differences between American and European teachers and pupils that account for the differences in systems?

Are educational objectives the same at home and abroad?

It was my good fortune to be able to spend a year in Europe, just before Hitler came into power, in search of material in answer to these and many other questions. Most of the time was given to a study of the teaching

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of chemistry in the secondary schools of Germany, Austria, France, and England. A total of three months was spent in German schools, the time being almost equally divided between the four cities, Berlin, Heidelberg, Freiburg, and Munich. Classes in the various kinds of schools were visited day after day. Conversations were held with professors, assistants, pupils, mature graduates, and school officials. All of them answered questions freely. The courteous and intelligent treatment everywhere accorded me made the work a pleasure.

The subject chosen naturally breaks up into the following divisions:

The German system, ideals and objectives, the pupil, the teacher, and class and laboratory practices.

THE SYSTEM

German education is bureaucratized to an extent difficult for an American teacher to understand. Before one can visit a class it is necessary to secure a permit from the state ministry of education. One of the most difficult situations encountered in my visit to Germany arose in the attempt to explain to one minister of education why I had no letter of introduction from the Minister of Education of the United States. It took an hour of arguing and a week of waiting for him to check the accuracy of my statements for me to obtain the permit.

For the most part the schools analogous to our high schools are under state control. There are a few under city control, especially schools for girls. The state ministries are closely connected with the national ministry. The state Minister of Education issues a printed set of regulations governing each type of school. The work of each semester is carefully laid down in each subject. No deviation in sequence of courses is permitted.

Throughout Germany there are three types of schools in which chemistry is taught. In the Berlin area there is a fourth type which will not be discussed here. These schools prepare for entrance to the universities and technical high schools. The three types have their curricula built around different language frameworks. The oldest type is the Gymnasium, often called the humanistic gymnasium. It is the ancient language school with requirements of nine years of Latin, six years of Greek, and seven years of French or English, as a rule. It prepares for the university.

The Oberrealschule is the modern language or science-mathematics school. It prepares for entrance into the technical high schools, and bases its curriculum upon a language requirement of nine years of French and six years of English.

The third type is the Realgymnasium, a compromise between the other types, which prepares its graduates for either type of university training. In it there are nine years of French and six years of Latin with four years of English either required or elective.

In these schools the chemistry taught increases both qualitatively and quantitatively from the Gymnasium to the Realgymnasium to the Oberrealschule. The variation in number of semester hours is 4:12:18. The total natural science requirements vary in the ratio 36:50:70 semester hours.

IDEALS AND OBJECTIVES

Due to the bureaucratic nature of German education a definite philosophy of education has developed, and has been accepted by the German people. Rigorous control over a long period has produced a system which definitely agrees with that philosophy. The scheme is not only national, but strongly nationalistic. Let me quote a few brief statements of the Prussian Minister of Education in 1931.

"The skeletal subjects, that is the cultural subjects to which German educational security is intrusted, shall make up one-third of the hours of each type of school.

"Every one of the special ideals of the several school-forms has a right to exist in the higher schools only if it stands in most intimate relationship to traditional German culture.

"A deep rooting in a special field of our cultural life is possible only through the curriculum of an individual type of school. Hence, it is necessary that each type have a specific and complete curriculum.

"In each of these fields the student's intellectual capacity for work will be reached, which will make possible his entrance into any of the higher schools and professions. Therefore, it is out of the question that any of these schools is a preparatory school for any profession or subject."

THE PUPIL

Practically all German children attend the tuition-free Volkschule from the age of six to nine and one-half years of age. At the age of nine and one-half years the educational future of the child is determined. If it is the desire of his parents that he prepare for one of the professions, he must transfer to one of the schools described. If such a decision is made, the boy or girl undergoes a simple examination to determine if he is fit for entrance. If he proves himself to be normal, he is passed. Only about ten per cent. of the children make the change. It is not considered even worth while to give the children of the peasants such an opportunity.

As a result, the pupils of these schools are selected as to ability and parental ambition. Tuition is graded on the parents' income, even being waived entirely for the very poor. It is only natural that not all of the pupils possess their parents' ambition for them, but they have been proved of normal intelligence, and the discipline of the schools, military in its rigidity, succeeds in educating them.

It is safe to say that the German boy hates school. The terms are long, and he has a great deal of homework. Several men whom I questioned on the subject

stated that they looked back upon their schooldays with a feeling akin to loathing. However, to a man, they approved of the system and declared they would not have it changed for their children.

THE TEACHER

By far the finest product of the system is the teacher. With education held in reverence by the people the teacher holds a position of esteem and respect difficult to describe to Americans. To the German a teaching position is something to be attained by long years of hard work. Unlike his American colleague, he is never bridging the gap between graduation and medicine, law, or matrimony. He is a member of a respected profession with assured employment for life, once he gets started.

He begins his specialization when he enters the university. There are special courses for him in the chemistry department and elsewhere. He does not work for the doctorate, since that only lengthens his university career. Of course, there are exceptions. Competition is so keen for entrance into the teaching profession that a minimum of eight semesters in the university is necessary. It is common for him to spend ten or even twelve semesters in the university.

When he considers himself sufficiently prepared to take the examinations the applicant applies to the state ministry of education. He gives several months to them. He has prepared himself in two majors, one minor, and philosophy. He writes two dissertations, one in one of his majors and the other in philosophy. After a couple of months, if these have proved satisfactory, he is called to the capital for further examination. He must write three-hour dissertations in chemistry, physics, and mathematics, if these are his majors and minor. The writtens are followed by one-hour orals in each major and half-hour orals in his minor and philosophy.

After a month or two the successful candidates are told to report to the schools where they are to do their practice teaching. There now follows a period of three or four semesters of very concentrated effort. The school faculty holds seminars for the practice teachers at least six hours a week. The director of the school instructs them in pedagogy. Toward the end of the period each candidate writes a dissertation on some subject which he wishes to present to the students. One such paper that I heard was "Introduction of Colloidal Chemistry to the Eighth Year Class." It was a beautiful piece of work. It is necessary for the candidate to teach three classes, possibly in three subjects, before a committee consisting of the state minister of education, the director of the school, and the professors of the departments in which he has been teaching. The committee then gives him an oral examination in pedagogy.

The successful survivor of this long ordeal is placed on the eligible list. In 1932 it was estimated that he would have to wait for from three to fifteen years for an opening.

It is obvious that none but men and women of very high intelligence and of unlimited perseverance and patience can become teachers. They are keen students and enthusiastic and sympathetic teachers. Unfortunately, they are so thoroughly shaped according to the pattern furnished by the ministry that they are very much of a type. Professors complained to me that they were afraid to experiment with their teaching methods for fear of having to explain to an unsympathetic minister. They recognize that they are to a far greater degree than their American colleagues "stuffers" of knowledge. They deplore their failure to develop originality in their pupils, but dare not take a chance with their jobs.

THE CLASS

The classroom is generally a well-equipped lecture hall. Behind it and connected to it by a door other than the one used by the pupils is a large well-equipped office and preparation room for the professor. The students enter the classroom before the bell. As soon as a sound is heard at the door of the professor's office all noise subsides and as the door opens every pupil springs to his feet and remains standing at attention until ordered to his seat.

The lesson almost invariably opens with a recitation over the material introduced at the last meeting. Some teachers carry on a very fine oral quiz to which the pupils generally respond more or less eagerly, if not always accurately. Here is evidenced both the rigid discipline of the German schools and the universality of evasion of careful preparation by pupils. Answers to questions vary from perfection to abject failure, and the attitudes of the other members of the class toward the one reciting are the same as those found in one of our own classrooms. Prompting is the rule, the German pupils being adepts at giving and receiving aid. Some of the professors seemed to overlook the practice, while others kept strict watch and meted out punishment to offenders.

I shall never forget the first recitation that I heard in a German school. It was under a teacher who is considered outstanding by university and secondary-school teachers. He opened the recitation by calling for three or four notebooks which he glanced through while the recitation was going on. A pupil was called on to recite. He gave one of the most fluent and exact recitations I have ever heard. He was abruptly stopped and asked a couple of questions which he answered satisfactorily. Another was called on, and he continued the recitation. I wondered whether I had been given the opportunity of witnessing the result of a perfect system or was in the presence of perfect students. However, the perfection of the recitation coupled with a possible suspicion of a singsong led me to delay my decision. The second pupil did not answer the specific questions quite so well. A third pupil had not been paying close attention and could not get started when called on. He had some sort of punishment meted out to him.

Following the recitation, I saw one of the finest demonstrations that I have ever witnessed on a lecture table. The apparatus, electrical appliances, microscopes, projectors, etc., would do justice to most colleges and many universities. The set-up was elaborate and exact in every detail. The whole thing was carried out in a masterful and almost spectacular fashion. The explanation accompanying each step was clear and exact. No one could fail to get the points involved. All reactions were explained by equations on the board. Day after day and hour after hour I saw similar demonstrations. I fear that very few American high-school teachers would compare favorably with German teachers in this connection.

Then came the lecture, and with it an explanation of the perfection of some of the recitations. The professor dictated slowly and meticulously, even dictating punctuations. He repeated long sentences exactly. The students took down the lecture in one of their notebooks. A few questions asked an assistant after the class cleared up the whole matter. The pupils were required to take the notebooks home and copy the lecture into another notebook to turn in. Then they memorized the lecture verbatim. American teachers must marvel at a discipline which will make such a system work for the great majority of the pupils.

At the end of the lecture the teacher prepared to leave the room. The pupils jumped to their feet and stood stiffly until the door closed. They then rushed from the room, munching rolls or sandwiches, or hurried to the cart in the court to buy rolls and milk Even the professors seem to require food between classes.

Textbooks play a very inferior rôle in German education. In some states possession of texts is compulsory, but their use is quite voluntary. In all of my visits I found only one teacher who made assignments in the text. He teaches in Berlin. I found other chemistry teachers in Berlin who considered texts a hindrance, rather than an aid. One professor of good reputation told me that he would not permit his first-year pupils to have texts and preferred that only the best members of his advanced classes own them. It was in Berlin, also, that I found the only school where lectures were tabu. The director would not permit them. It was the firm belief of every teacher questioned that to have a pupil read in his text in advance of the lecture would be worse than a waste of time.

LABORATORY CLASSES

There is great divergence of opinion among German teachers as to the value of laboratory work. In some schools it has been curtailed, due to lack of money, and it would be expanded if possible. Several teachers believe in and practice the policy of making all laboratory work elective and limit it to a few picked students. In one Oberrealschule in a city in Baden I found two hours a week required for all pupils throughout the four years of chemistry, even though laboratory work is elective by law in Baden. In another Oberrealschule in the same city I found the work optional and limited to ten members of each class, though the school had large and well-equipped laboratories. In some Berlin schools laboratory work is compulsory, while in others of the same type it is optional. In Bavaria no exceptions are supposed to be made to the rule requiring laboratory work in all classes. Where the work is elective it is generally left to the student to decide what he will do and to a considerable extent how he will do it, even though he has had no introduction to systematic experimentation except by observation.

In the laboratory classes that I visited no freedom was left to the pupils. Apparatus and materials were placed before them, and they were told every move to make and just what to see at each point. As a rule the teachers talked a great deal during the exercise, asking many questions which they almost always answered without attempting to get an answer from the class. The work was carried out with almost the precision of military drill and very little, if anything, was left to the imagination of the pupils. In the laboratory, as in the classroom, the pupil never ventured a question.

I recall one very amusing incident. I was present at a meeting of the seminar for practice teachers when a young woman reported on an educational experiment she had just carried out with one of her classes. She had explained what she intended to do at the last meeting of the seminar, and freely admitted that they had been right in predicting failure. What she had done was to make the usual demonstration and give the lecture on a new subject; then she sent the pupils into the laboratory with instructions to work out their own experiments. They made a terrible mess of it. In all probability it was the first time that any of them had ever been permitted to do anything by himself in the laboratory, and they were completely lost without the usual detailed instructions. I shocked the seminar when I was called on for my opinion in the matter and told them that the very method they were so thoroughly condemning was the one considered best by many of our most successful teachers. I was afraid to tell them that some good teachers start their study of some subjects by such free experimentation on the part of the pupils. They were too polite to tell me that I surely must be mistaken, but I was certain that some of them felt that I was.

CONCLUSION

My study has led me to believe that the strength of the German system of secondary education lies in the universal reverence in which education is held by the people, in the careful selection of pupils, in the wonderful preparation of teachers, and in the rigorous discipline maintained in the schools. Since not one of these conditions appears to me to be at all possible with us, I have come to the conclusion that there is very little that we can hope to borrow from our German colleagues.

A SUGGESTED PLAN *for* CLOSER COÖPERATION *between* TEACHERS *of* PREPROFESSIONAL CHEMISTRY *and* BIOCHEMISTRY*

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COÖPERATION between teachers of premedical and predental chemistry in liberal arts colleges and teachers of biochemistry in medical and dental schools is surprisingly lacking. For the most part teachers of preprofessional students go their own way, while teachers of biochemistry in the medical and dental schools take little interest in what is being taught in chemistry to students who eventually will be in their classes. Preprofessional courses in general chemistry, organic chemistry, and analytical chemistry vary so greatly in colleges of liberal arts that semester-hour credits submitted for entrance to a medical or dental school may mean a great deal in one case and very little in another. The teacher of biochemistry usually has in his class students poorly prepared in chemistry and others exceptionally well prepared. To bridge the gap, much material has to be given which should be non-essential.

In the particular plan to be described, the results of ten years of experience are available. To start with, in the spring of the year, a preprofessional visiting day is arranged so that students contemplating the study of medicine and dentistry may see for themselves just what such studies entail. A tour of the schools is made, and preprofessional students have opportunities to talk with faculty members and students in the two schools. Premedical and predental advisers are urged to take advantage of the visiting day so that they will be better able to advise their students what the studies of medicine and dentistry comprise. The jump from study requirements in a liberal arts college to those in a medical or dental school is a big one, and unless a student is prepared for it he may get lost in the shuffle during the first few months of his professional studies. It has been found that after acquainting themselves definitely with the heavy requirements of a health service school students often give up their plans for entrance, while others may decide to go into one of the fields. Visiting day has worked out so well in the plan that we would not think of giving it up.

Each year before the course in biochemistry begins, heads of chemistry departments in colleges where the freshmen students prepared in the subject receive a letter giving the names of their former students in the class and are told that from time to time during the semester descriptive reports of their students' work will be sent to them. Premedical and predental grades are obtained from the dean and tabulated, but various aptitudes of students are usually not well described to deans of medical and dental schools. The preprofessional teachers are asked to coöperate in this respect by sending on their estimates of each student in matters other than those covered by grades. When the biochemistry course begins, each instructor in the course is acquainted with the background of every student, not only from a chemistry grade standpoint, but rather generally. Prejudice, obviously, has to be kept out of the picture carefully. As the course proceeds, the premedical chemistry teachers are informed concerning their students' work, the grades being incidental. At the close of the course, final grades are sent and are recorded on the cards of the respective colleges held by the professor of biochemistry. After the plan has been under way for a number of years, the chemistry representative on the admissions committee knows from these cards what colleges prepare students well in premedical and predental chemistry and those which do not. Since the greatest number of hours in any premedical, and to a large degree now, predental course is required in chemistry, the facts learned from the plan help greatly in selecting students.

Each matriculating freshman in the course in biochemistry, knowing of the plan as carried out, feels a responsibility to his preprofessional college and chemistry teacher, and perhaps oftentimes does better than he would otherwise.

Each chemistry department head in the colleges concerned is sent an outline of the biochemistry course. With the aid of the outline, preprofessional chemistry teachers feel that they know more in detail what to stress with their premedical and predental students, and consequently prepare them better. This does not mean that any attempt is made to give specialized courses to preprofessional students but simply to make

* Presented before the Division of Chemical Education at the Ninety-first Meeting of the American Chemical Society, Kansas City, Missouri, April 15, 1936.

the fundamental ones more practical.

From time to time, members of the chemistry department in the medical and dental schools visit the chemistry departments of preprofessional colleges supplying students. Knowledge of mutual problems aids greatly in better all-round instruction.

An OBJECTIVE-TYPE TEST *for* ORGANIC CHEMISTRY*

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WHATEVER else may be said about objective tests, and a great deal has been said, it is generally recognized that they do conserve the teacher's time, are easy to grade, and give some measure of the student's progress. Objective tests have not been used to any extent in organic chemistry, yet this particular branch of the science lends itself to such tests, as this paper will attempt to show.

Reaction charts of the type used by Underwood,[1] Colbert,[2] Hauser,[3] and others are made up for one or more organic families, depending upon how comprehensive the test is to be. Numbers are substituted in place of the main product or reactant in each individual reaction as shown in Figure 1. The student is expected to place the correct formula for a given product opposite the same number at the side of the sheet.

* Presented before the Division of Chemical Education at the Ninety-first meeting of the American Chemical Society, Kansas City, April 14, 1936.

[1] UNDERWOOD, H. W., "Problems in organic chemistry," McGraw-Hill Book Co., Inc., New York City, 1926, 233 pp.

[2] COLBERT, J. C., "A shorter course in organic chemistry," The Century Co., New York City, 1931, 352 pp.

[3] HAUSER, C. R., "Chart illustrating organic-reactions of the aliphatic series," J. CHEM. EDUC., 11, 179 (Mar., 1934).

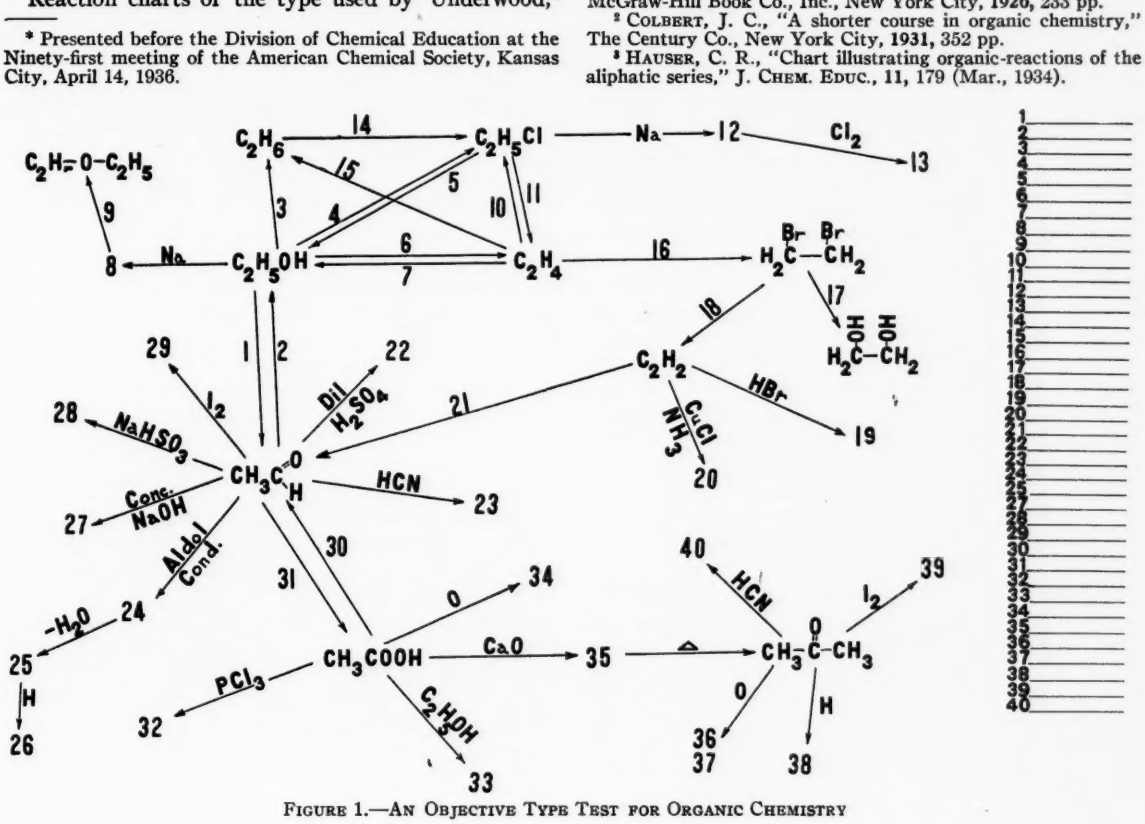

FIGURE 1.—AN OBJECTIVE TYPE TEST FOR ORGANIC CHEMISTRY

In this way the grading can be easily accomplished by the use of a key.

Since the experimental conditions play such an important part in determining the course of an organic reaction, it is well to insist that the student give those conditions in so far as it is reasonably possible to do so. For example, when ethylidene dibromide is treated with *aqueous* potassium hydroxide solution, glycol is formed; but if an *alcoholic* potassium hydroxide solution is used, acetylene is the product. This is illustrated by numbers 17 and 18 in Figure 1. Then the student would be expected to answer number 17 by writing aq. KOH and number 18 by alc. KOH in the suitable spaces. The statement of other conditions, such as suitable temperatures, catalysts, etc., could be required at the discretion of the instructor.

It is too much to expect that this kind of test will entirely take the place of the usual type of monthly or final examination. It is offered solely as a supplement to these tests. The writer is still "old fashioned" enough to believe that an essay type test helps the student to organize his knowledge and thinking by writing out in some detail the answer to a question. However, since many of these examinations contain questions concerned with the writing of equations, this type of objective test would be useful. It might also be used alone at certain intervals of, say, two or three weeks, solely for the purpose of determining how much the student has learned about the organic reactions of the family or families just studied.

The argument may be raised that the student does not learn to complete and balance equations by this method of testing. Of course he should learn that during his study and class periods but, after all, most organic reactions are relatively simple to balance when the main product and the reactants are known. The fact that the test, in common with reaction charts, teaches correlation between various compounds and families offsets this weakness, in the author's opinion.

Summary.—An objective type test, based on the use of reaction charts, is proposed. It is useful for determining the student's knowledge of organic reactions at frequent intervals or as a supplement to the usual monthly or final examinations.

A MODIFICATION OF THE BETTENDORF TEST AS A CONFIRMATORY TEST FOR ARSENIC IN QUALITATIVE ANALYSIS

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STUDENTS in elementary qualitative analysis often fail to get decisive confirmatory tests for arsenic by use of reagents such as silver nitrate, magnesium salts, or ammonium molybdate. The modified Bettendorf test, described here, requires less manipulative skill than the tests by the reagents just named and has been found quite satisfactory for the use of freshmen students at this institution.

To use this test, separate arsenic from antimony and tin by any usual method which leaves arsenic in the form of a sulfide precipitate. Transfer the precipitate to a beaker, add 10 ml. of 6 *M* perchloric acid and heat till dense white fumes are copiously emitted. Then add 10 ml. of 12 *M* hydrochloric acid and 5 ml. of 0.5 *M* stannous chloride, heat the mixture to boiling, and allow it to stand one minute without further heating. The formation of a dark brown solution indicates the presence of arsenic. The coloration is due to the presence of free arsenic.

The further manipulation described in this paragraph was suggested by King and Brown[1] and should be used when no brown coloration appears in the solution after it has stood one minute. In a separate vessel thoroughly mix 1 ml. of 0.25 *M* mercuric chloride with 9 ml. of water, add 1 ml. or less of this mixture to the solution being tested for arsenic, stir, and allow the final mixture to stand for ten minutes. If the solution is colorless at the end of ten minutes, arsenic is absent. Although this test is very delicate and certain, the reactions are often slow, and time is required for the formation of the brown coloration. According to King and Brown[2] mercuric chloride catalyzes the reactions and thus hastens the appearance of the brown coloration.

The following remarks will indicate the particular utility of the manipulation to persons lacking recent experience with the Bettendorf test. The Bettendorf test consists of the reduction of dissolved arsenite or arsenate to free arsenic by stannous chloride in concentrated hydrochloric acid solution. Boiling temperatures and high hydrochloric acid concentrations favor reaction. Although the Bettendorf test is one of the more simple and easily executed arsenic tests, it has not been used as a confirmatory test in qualitative analysis because oxidizing agents, other than arsenite or arsenate, must be absent, and nitric acid, an oxidizing agent, is the only reagent commonly used to dissolve arsenic sulfide before making a confirmatory test. Perchloric acid has the useful quality of acting as an oxidizing agent in the hot fuming condition and of not being an oxidizing agent when somewhat diluted. Hence, perchloric acid may be used to dissolve arsenic sulfide, and later, when somewhat diluted, perchloric acid does not interfere with the Bettendorf test.

[1] *Ind. Eng. Chem., Analyt. Ed.*, **5**, 168 (1933).

[2] *Loc. cit.*

CRYSTAL CHEMISTRY

VI. THE PROPERTIES OF BINARY COMPOUNDS. CONCLUDED

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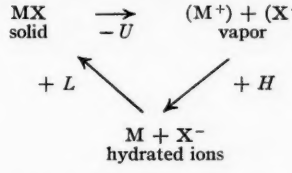
SOLUBILITY

IN ADDITION to the properties previously discussed, solubility is, in a sense, an indication of the strength of a crystal.

A salt is soluble in water when the attraction of the ions for water molecules is stronger than the attraction of the ions for each other; or, to put it a bit more precisely, when the energy of hydration is greater than the lattice energy. In general, the small cations may be expected to exert a greater attraction for water than do anions, but since the water molecule is asymmetric, it may be shown that a negative ion will have a higher energy of hydration than a positive ion of the same size (*107*).

It is difficult to make a direct calculation of the heat of hydration (an approximation of the energy of hydration) of an ion because several layers of water surrounding the ion contribute to this value. Possibly the number of water molecules in the first layer is determined by the radius ratio rule. We may approach the heat of hydration indirectly through the relationship $-U = H + L$, where U = lattice energy, required to dissociate the solid into vapor ions; L = heat of solution at infinite dilution, the energy required to convert the solid into a dilute solution; H = heat of hydration, and approximation of the energy involved in the hydration of the vapor ions. We then have the cycle



The heat of solution may be determined experimentally. The lattice energies are, of course, available. Since heats of hydration are measured at infinite dilution, in a compound A_X, H_{A+} will be unaffected by H_{X-}. The heats of hydration of the ions are additive, so that $H_{A+} + H_{X-} = H_{AX}$. From the heats of hydration of the alkali halides, and similar data it has been possible to compute values for heats of hydration of the ions shown in Table 41.

TABLE 41

(VAN ARKEL AND DE BOER, p. 212) HEATS OF HYDRATIQN OF SEVERAL IONS IN KCAL.

H^+	Li^+	Na^+	K^+	Rb^+	OH^-	F^-	Cl^-	Br^-	I^-
255	131	98	77	73	ca.80	123	83	73	63

The heat of hydration increases with decreasing size of the cation or anion, and with increasing valence. The heat of hydration of a B-cation is greater than that of an A-cation of the same size and valence. This is probably due to the strong polarizing effect of the former and its tendency to form a covalent bond.*

Solubility may also be pictured as the result of the weakening of the bonds within the crystal by the solvent, according to the relation

$$F = \frac{e_1 \times e_2}{d^2 \times D}$$

where F = attractive force between ions; e_1 and e_2 = charges on ions, d^2 = distance between ions, D = dielectric constant of solvent. Thus, water is a good solvent for ionic crystals because it is a strong dipole and has a high dielectric constant which tends to neutralize the forces between the ions. The polar water molecules surrounding a crystal may be considered to penetrate the lattice, pry the ions apart and carry them away. In many cases they are not carried far. For example, it is rather surprising to learn that in a saturated solution of sodium chloride the Na^+ and Cl^- ions are only about twice as far apart as they are in the crystal.

Solubility and Ionic Radii.—The relation of solubility to ionic radii or interionic distances is shown for the alkali halides, in Table 42 and for the alkaline earth halides and the halides of zinc and cadmium in Table 43.

TABLE 42

SOLUBILITIES OF THE ALKALI HALIDES (MOLS IN 1000 PARTS WATER) AT 0°C. (UNLESS INDICATED IN PARENTHESES)

	F	Cl	Br	I
Li	0.1 (18°)	16		11
Na	1.0 (15°)	6.1	11	10
K	16 (18°)	3.7	4.5	7.6
Rb	12 (18°)	6.4	5.8	6.5 (6.9°)
Cs	24 (18°)	9.6	6.0 (25°)	1.7

* In the discussion of properties which follows, we shall consider the peculiar influence of the B-cations in relation to their tendency to form the covalent bond and their ability to deform large anions or polar molecules. It must be emphasized that while the influence of the covalent bond is generally thought to be more significant, it is not necessarily so in all cases. One may assume a small positive ion which has drawn toward itself the electron cloud of a large diffuse negative ion; or one may picture a bond partly ionic and partly covalent, the time average position of the electron pair being, not halfway between the two atoms, but toward the negative atom. In either case the ultimate distribution of electrons around the two atoms is essentially the same; the average position of the electron pair is toward the electronegative element. The terms "deformation" or "polarization" and "mixed bond" are used somewhat arbitrarily in this discussion.

TABLE 43

SOLUBILITIES OF THE DIVALENT HALIDES (MOLES/LITER)

	F	Cl	Br	I
Mg	0.0012 (18°)	5.6	5.0	4.3
Ca	0.0002 (18°)	5.36	6.25	6.0
Sr	0.0009	2.7	3.4	4.8
Ba	0.009	1.5	3.3	7.5 (40° – $BaI_2 \cdot 2H_2O$)
Zn	trace	32 (25°)	26 (40°)	14
Cd	0.3 (25°)	5.0	2.25	2.2

It is difficult to find any consistent trend in these data, nor is this surprising, since solubility is influenced by lattice energy and heat of hydration and these are affected differently by ionic radii.

Solubility and Valence.—With increasing valence, the lattice energy of *ionic* crystals increases much more rapidly than does the energy of hydration. The term $e_1 \times e_2$ in the expression $F = \frac{e_1 \times e_2}{d^2 \times D}$ also increases. Thus solubility decreases very sharply as valence increases, as shown by typical data listed in Table 44. This table may, of course, be greatly extended and the trend will be found to be consistent.

TABLE 44

SOLUBILITY *vs.* VALENCE (A-X DISTANCES RELATIVELY CONSTANT) (MOLS/LITER)

Valence	1–1	2–1	2–2	3–2	4–2	3–3	4–4	3–1	4–1
	LiF	MgF_2	MgO	Al_2O_3	TiO_2	ScN	TiC	Layer	Molecular
A-X Dist.	2.02	1.99	2.10	1.90	1.96	2.23	2.23	Lattice	Lattice
Solubility	0.1	0.0002	0.00015	i.	i.	i.	i.		
	NaF	CaF_2	CaO	ThO_2				$AlCl_3$	$ThCl_4$
A-X Dist.	2.31	2.36	2.40	2.42					
Solubility	1.0	0.0002	i.	i.				6.0	v. s.
	NaCl	BaF_2	BaO					$PrCl_3$	SnI_4
A-X Dist.	2.81	2.68	2.77						
Solubility	6.1	0.009	0.1					4.2	v. s.

v. s. = very soluble; i. = insoluble.

Evidently no general statement can be made regarding the dependence of solubility upon valence, although there is no question as to how they are related. In the first horizontal row and in the first three vertical rows are typical ionic crystals (except ScN and TiC) and, as valence increases, solubility drops rapidly; in fact, only the uni-univalent salts show an appreciable solubility, and of the halides of copper, silver, and thallium, only the fluorides. Passing from the strictly ionic crystals, into the field of atomic crystals (ScN, TiC), layer lattices ($AlCl_3$ and $PrCl_3$) and molecular crystals ($ThCl_4$ and SnI_4), the strength of the crystal, as measured by stability, is, of course, no longer directly controlled by valence.

Solubility and Electronic Structure of the Ions.—A B-cation exerts a strong polarizing effect and an increasing tendency to form the covalent bond and the lattice energy and the energy of hydration are both higher than they are for an A-cation of the same size and valence. Whether, in substituting a B-cation for an A-cation, heat of hydration or lattice energy increases to a greater extent appears to depend upon whether water or the negative ion of the compound can be more strongly polarized. If the anion is more easily deformed than water, lattice energy may be expected to increase more rapidly than heat of hydration; and the compound with the B-cation is less soluble. If the anion is less easily polarized than water, the heat of hydration increases more rapidly than the lattice energy, and the solubility of the B-cation compound is greater; that is, the B-cation tends to form a stronger bond with water molecules, rather than with the anions. The effect of this relationship is shown in Table 45.

TABLE 45

SOLUBILITY *vs.* ELECTRONIC STRUCTURE OF THE CATION

	F	Cl	Br	I	
Na^+	1.0	6.1	11.3	10.6	Mols/1000 g. of water
Ag^+	14.0	6×10^{-3}	4.5×10^{-7}	1.3×10^{-8}	
Tl^+	3.6	9×10^{-3}	8.5×10^{-4}	6×10^{-5}	
Hg_2^{++}	forms Hg_2O	4×10^{-6}	3×10^{-10}	6×10^{-10}	

The fluorides (and chlorates and nitrates) of the B-cations are more soluble than those of the corresponding alkalies, probably because water is more strongly polarized than the fluoride ion. The other halides of B-cations are less soluble than the alkali halides because the halogen is more strongly polarized than water.

The same sort of relation is found among the divalent ions. Because the anion is more strongly polarized than water (*e. g.*, $O^=$, $S^=$), or, as is more likely in this case, because of the growing influence of the covalent bond, the compounds of the B-cations are less soluble than those of the A-cations. Thus, ZnO, ZnS, CdS, HgO, CuO, FeO, NiO, etc., are less soluble than CaO, BaO, CaS, BaS. If the water is more strongly polarized than the anion, then the reverse is true; $CaSO_4$, $SrSO_4$, and $BaSO_4$ are less soluble than $ZnSO_4$ and $CuSO_4$. Furthermore, within the series of alkaline earth salts there are interesting variations in solubility, probably as a result of deformation. Compare the solubilities of the alkaline earth sulfates and hydroxides in Table 46.

TABLE 46

SOLUBILITIES OF ALKALINE EARTH SULFATES AND HYDROXIDES

$MgSO_4$	26.9	$Mg(OH)_2$	0.0009	G./100 g. water
$CaSO_4$	0.176	$Ca(OH)_2$	0.185	
$SrSO_4$	0.011	$Sr(OH)_2$	0.41	
$BaSO_4$	0.0001	$Ba(OH)_2$	4.29	

Of the sulfates, $MgSO_4$ is the most soluble, possibly because Mg^{++}, which is the smallest cation, has the greatest polarizing effect on water, which is easily deformed. With the hydroxides, however, the reverse is true. The hydroxyl ion is more easily polarized than water; hence, the smallest cation may polarize it the most, and it forms the least soluble hydroxide. MgO is less soluble than CaO, while $MgSO_4$ is more soluble

than $CaSO_4$; Mg^{++} is more strongly polarizing than Ca^{++}, and O^{-} is more strongly polarized than $SO_4^{=}$.

This polarizing influence may account, too, for the high solubility of certain salts of sodium, as compared with those of K, Rb, and Cs and of Mg as compared with Ca, Sr, Ba, and Ra, as shown in Table 47 (*108*).

TABLE 47

SOLUBILITIES OF SOME ALKALI SALTS. MOLS/LITER

	Na	K	Rb	Cs
$MClO_4$	v. s.	0.11	0.41	0.05
M_2PtCl_6	v. s.	23×10^{-4}	24×10^{-4}	1.17×10^{-4}
$MAl(SO_4)_2$				

	Mg	Ca	Sr	Ba	Ra
MSO_4	2.16	7.8×10^{-3}	5.3×10^{-4}	9.7×10^{-6}	6.5×10^{-8}
MC_2O_4	2.7×10^{-3}	4.2×10^{-5}	24×10^{-5}	33×10^{-5}	

Sodium and magnesium are relatively small and strongly polarizing ions and water is polarized more easily than the ClO_4^{-}, $PtCl_6^{=}$, $SO_4^{=}$, and $C_2O_4^{=}$ ions.

All this has a very interesting bearing upon our scheme of qualitative analysis as shown in Table 48 (*108*). To precipitate the univalent B-cations we add an ion (Cl, Br, or I) which is more strongly attracted than is water. If we were to add H_2F_2 as a first group reagent, instead of HCl, the alkali cations would be precipitated at that point. The HCl does not precipitate the divalent B-cations or any trivalent or quadrivalent cations because the halides of these form weak, and therefore soluble, layer or molecular lattices. To precipitate the divalent B-cations we add a divalent sulfide ion which will be polarized more strongly than water and also tends to form a mixed bond, not so easily broken by water. This precipitates an AX compound, thus avoiding the formation of a layer lattice. With an acid sulfide we are able to precipitate most of the remaining B-cations, the cations of the larger transition elements and even the largest (V^{+5} and W^{+5}) of the A-cations. The smaller transition cations and the trivalent and quadrivalent A-cations, however, are precipitated from basic solution: the precipitation of some of them depends upon the attraction by the cation of the very polarizable hydroxyl ion to form an insoluble hydroxide. Only the alkaline earths and alkalies are left. We expect the alkaline earths to be separated from the alkalies by a divalent anion because of the known influence of valence upon solubility.

It is evident that certain salts, particularly those of the B-cations can be dissolved in ammonia when they are insoluble in water. Although ammonia is a weaker dipole than water, it can be more strongly polarized, and when in a strong electric field, its reduced dipole moment is greater than that of water. The B-cations can attract ammonia more strongly than water. The ammonia molecule contributes its extra electron pair to the bond, tending to form a mixed ionic-covalent bond in most cases. We find that ammonia can break down the AgCl, AgBr, and AgI lattices, whereas water fails. Similarly, salts of Zn, Cd, and Cu form ammonia complex ions which are soluble and stable in solution. Of the A cations Mg^{++}, since it is the smallest and most strongly polarizing of the alkaline earths, is soluble in ammonia.

TABLE 48

SCHEME OF QUALITATIVE ANALYSIS

Reagent	HCl	H_2S Acid Solution				$(NH_4)_2S$				$(NH_4)_2CO_3$		
Ions precipitated	Ag^{+} Tl^{+} Pb^{++} Hg^{+}	Cd^{++} Hg^{++} As^{+5} Sb^{+5} Bi^{+5} Sn^{+4}	Ge^{++} Sn^{++} Pb^{++} As^{+3} Sb^{+3} Bi^{+3}	Cu^{++} Ru^{+3} Rh^{+3} Pd^{++} Os^{+4} Ir^{+3} Pt^{+4}	V^{+5} W^{+5}	Fe^{++} Co^{++} Mi^{++} Cr^{+3} Zn^{+} Mn^{++}	Ti^{++} Zr^{++} Ce^{++} Th^{++}	$Al^{+3}Be^{++}$ Sc^{+++} Y^{+++} La^{+++} Ce^{+++} Rare earths		Mg^{++} Ca^{++} Sr^{++} Ba^{++} Ra^{++}		Na^{+} K^{+} Rb^{+} Cs^{+}
No. of valence electrons	1–2	2–5	2–3	2–4	5–6	2–3	4	3	2	2	1	1
No. of outer electrons	18	18	18 + 2	T	8	18 T	8	8	2	8	2	8

T = transition ion.
Mg^{++} precipitates as the carbonate only in the absence of NH^{+4}.

HYDROLYSIS. ACIDS AND BASES

Salts of weak acids or weak bases, particularly those of metals whose hydroxides are insoluble, hydrolyze when dissolved in water. The OH^{-} ion is very easily polarized, and, in accordance with the principles which have been outlined, we may expect the hydroxides of the smaller cations and of the B-cations to be particularly insoluble or only weakly ionized, since these are the cations which will exert the strongest polarizing influence upon the OH^{-} ion. A correlation of the electronic structure of the ion with the tendency to hydrolyze arises out of the fact that those ions which can polarize the OH^{-} group most strongly are those most apt to hydrolyze. It follows that hydrolysis should take place to a greater extent with small cations than with large ones. Thus, of the fourth group chlorides, $ThCl_4$, $HfCl_4$, $ZrCl_4$, $TiCl_4$, $SiCl_4$, and CCl_4, the degree of hydrolysis increases in the order $ThCl_4$ to $SiCl_4$. $ThCl_4$, in fact, hydrolyzes very little and shows considerable tendency to ionize. For the A-cations in the second group, hydrolysis increases in the order Ba^{++} to Be^{++}.

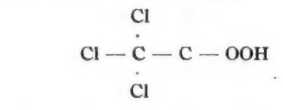
The tendency of a compound to hydrolyze increases with the valence of its cation. Only the alkali and alkaline earth salts undergo relatively little hydrolysis. Hydrolysis is marked for the trivalent aluminum ion and others of both the A and B sub-groups, and is practically complete for most cations whose valence exceeds three. Of course, the B-cations hydrolyze more strongly than A-cations of the same size and valence.

Acids and Bases.—All oxides form hydrates. The question arises as to why some split off OH^{-} ions to

form bases and others split off H^+ ions to form acids. In part, the answer to this question has been anticipated. No doubt the size of the positive ion and the nature of the bonding forces are of paramount importance in influencing the hydrated oxide to become a base or an acid. A hydroxyl ion is not attracted as strongly to a large cation of low valence as it is to a small cation of higher valence; that is, the reaction $MOH \longrightarrow M^+ + OH^-$ proceeds more readily for the larger, univalent, and divalent cations—the base-forming cations.

Acids and bases were discussed from a slightly different angle some years ago by Kossel (*109*) and later by Lewis (*110*). Consider the compound MOH. If M loses electrons easily (*i. e.*, if it is large and of low valence) the M-OH bond is weak and a base is formed. But if M has a strong attraction for electrons (*i. e.*, is small, highly charged and tends to form an electron pair bond) the electron cloud around oxygen is drawn toward M, thus weakening the O-H bond and allowing the hydrogen to break off and form an acid.

Thus, NaOH is basic because sodium gives up its valence electron readily. ClOH is acid because the chlorine has a strong attraction for electrons and tends to draw them away from the O-H bond. Acetic acid is weak acid; but if chlorine atoms are substituted for the hydrogens of the methyl group,



they tend to draw the outer electrons of all the atoms in the molecule to themselves. Thus, the O-H bond is weakened as the number of substituted chlorines increases and the strengths of mono-, di- and trichloracetic acids increase in the order named.

This sort of analysis may be carried throughout the periodic table and, as is well known, the change "base to acid" shifts further to the right for each succeeding period, somewhat as follows:

1.	Period	LiOH	$Be(OH)_2$	$B(OH)_3$		
2.	Period	NaOH	$Mg(OH)_2$	$Al(OH)_3$		
3.	Period	KOH	$Ca(OH)_2$	$Sc(OH)_3$	$Ti(OH)_4$	
		CuOH	$Zn(OH)_2$			
4.	Period	RbOH	$Sr(OH)_2$	$Y(OH)_3$	$Zr(OH)_4$	$Cb(OH)_5$
		AgOH	$Cd(OH)_2$	$In(OH)_3$		
5.	Period	CsOH	$Ba(OH)_2$	$La(OH)_3$	$Hf(OH)_4$	$Ta(OH)_5$
		AuOH	$Hg(OH)_2$	$Tl(OH)_3$	$Pb(OH)_4$	

In each case the last hydroxide given is amphoteric and the next element to come is acidic. The influence of ionic size on basicity is clearly shown. In this connection the basicity of the rare earth is of interest. $La(OH)_3$ is rather strongly basic, but the rare earth cations become less basic in character from lanthanum on, due to their decreasing ionic radii.

Evidently the B-cations, which exert a greater attraction for the easily polarized hydroxyl group and have a stronger attraction for electrons than the A-cations, tend to prevent the OH^- group from splitting off to give a basic solution. We find $Zn(OH)_2$ amphoteric in the third B-sub-group, as compared with $Ti(OH)_4$ in the A-sub-group; and $In(OH)_3$ in the fourth B sub-group, as compared with $Cb(OH)_5$ in the A sub-group.

Several useful applications of this correlation of acidity with ionic size and ionization potential might be described. A recent study of the acid strength of inorganic cations and the basic strength of inorganic acetates in acetic acid may be cited (*111*). The dissociation of inorganic acetates in acetic acid decreases (*i. e.*, the bond $C_2H_3O_2$-metal becomes stronger) with decreasing size and increasing charge of the metal ion. The acid strength of cations in acetic acid increases with decreasing size and increasing charge of the cations.

COLOR OF CRYSTALS

A crystal of copper sulfate transmits blue light because there are electrons in the crystal which change energy levels in the proper regions to absorb all the rest of the white light which enters the crystal; thus, only blue light passes through it. A strong ionic crystal like NaCl is colorless and transparent because all the electrons are so tightly held that their vibration is not of the proper frequency to absorb any light passing through them. The same is true of strong covalent crystals like the diamond. Color is found among those crystals in which intermediate bonds prevail.

The color of the ions of the transition elements has been attributed (*112*) to the electrons which are able to shift from the outer valence shell to the adjacent 18-shell. In the same way, as Lewis suggested some time ago (*113*), the color of the other binary compounds may be associated with a loosening of the electron structure, which is characteristic of the mixed bond. He represented such a state by placing the shared electron pair nearer the negative atom; thus Ag:I, rather than half way between (Cl:Cl), their position in the normal covalent bond. The same loosened bond is to be expected as a result of deformation when a strongly polarizing B-cation combines with an easily polarized anion (*114*). *The colored binary compounds are restricted entirely to compounds of the transition elements and B-cations.*† The relation between intensity of color and this "loosening" of the electron structure is clearly shown in Table 49. As the electrons are loosened to the point where they are able to absorb visible light, the first color produced is yellow, and with further loosening the other colors follow. The silver halides offer a typical example. The fluoride crystallizes in the NaCl structure, and the F^- ion is not polarized; the salt is colorless. With the more easily polarized Cl^-, the color appears and increases in intensity with the change Cl^- to Br^- to I^-, which is accompanied by a loosening of the lattice. The case of ZnO is interesting. Evidently zinc is the least polarizing of the group and does not produce a colored oxide. When zinc

† But the very unstable compounds CaCl and BaCl have been prepared and, as might be anticipated, are highly colored. R. ABEGG, Hand. d. anorg. Chem., Vol. II, pp. 105, 253, Leipzig, 1905.

oxide is heated, however, the heat augments the loosening effect and the oxide assumes a yellow color which is lost again when the temperature falls. This is not due to an allotropic change. A color change, possibly of the same type, is familiar in the ruby which changes from red to green when it is heated above *ca.* 400°C. There is no evidence to indicate that this color change is due to another crystalline form (*115*). That the positive ions shown in Table 49 are not colored in

TABLE 49

THE COLORS OF BINARY SALTS

	F	Cl	Br	I	O	S	SO_4	H_2O	NH_3
Na	c.	c.	c.	c.					
Cu II.	c.	yellow brown	brown black		black	black	c.	blue	darker blue
Ag	c.	faint yellow	yellow	dark yellow	brown black	black	c.		
Hg	c.	c.	yellow	yellow					
Zn	c.	c.	c.	c.	c. yellow	c.	c.		
Cd	c.	c.	yellow	brown	brown	yellow	c.		
Hg II.	c.	c.	yellow	yellow red	red or yellow	red or black	c.		
Pb II.	c.	c.	yellow	yellow	c.	black	c.		
Sn II.	c.	c.	yellow	red	c.	yellow	c.		

themselves is proved by the existence of the colorless fluorides and sulfates—anions which resist polarization and tend to form an ionic bond. It follows without question, therefore, that the color of these compounds is due to a property of the bond between the ions—a result of their interaction upon each other. The Pb^{++} ion and the I^- ion are colorless, but the brilliant yellow of PbI_2 appears when they are combined.

It will be apparent later that the brilliant colors of many of the Werner complex compounds are due to the loosened electronic bonds between the metal atom and its coördinated molecules. The Cu^{++} ion, for example, is colorless, but the $Cu(H_2O)_4^{++}$ ion is blue, and the $Cu(NH_3)_4^{++}$ ion is a more intense blue. Recently the cupric hydrate of heavy water, $Cu(D_2O)_4^{++}$ has been described as greener than the $Cu(H_2O)_4^{++}$ ion, and less intense in color (*116*), which suggests less loosening and less deformation of the D_2O molecule.

It is evident that color appears in those substances which are characterized by a high molecular refractivity; the same loosening of electrons is responsible for both phenomena—color and high refractivity.

ELECTRICAL CONDUCTIVITY BY IONIC DIFFUSION

The electrical conductivities of molten ionic salts are of the same order of magnitude, but the electrical conductivities of these same crystalline salts show great differences (*117, 118*). The order of these differences is shown in Table 50, in which the values in Column 2 are the ratios of the conductivities of the melts, just above the melting points, to the conductivities of the crystals just below the melting points (*119*) A striking feature of these data is that the conductivity of solid AgI is actually about ten per cent. greater than that of molten AgI, which is to be attributed to the loosened structure, the weak intermediate bond resulting from the extreme polarization in AgI. It has also been suggested that the high ionic conductivities of crystals of this structure are due to the presence of empty spaces in the lattice of the metal ions, permitting diffusion of the latter (*120*). This, of course, does not account for the marked conductivity of AgBr (NaCl structure) as shown in Table 50. When AgBr

TABLE 50

ELECTRICAL CONDUCTIVITY IN THE REGION OF THE MELTING POINTS COND. ABOVE M. P./COND. BELOW M. P.

KNO_3	20,000
$LiNO_3$	10,000
KCl	9,000
NaCl	3,000
TlCl	160
TlBr	130
TlI	100
AgCl	30
AgBr	5
AgI	0.9

acts as a conductor, the silver ions are said to migrate, leaving empty spaces in the silver lattice, while the bromide ions do not move (*121*).

It is quite evident that ionic conductivity in solids bears a definite relation to the predominant type of bond in the crystals (*122*). This is illustrated by the "degeneration" of a silver ion to a metallic silver atom via the solid series $AgNO_3$, AgCl, AgBr, AgI, Ag_2S, Ag_2Te, Ag_3Sb, Ag_4Sn, Ag_3Au, Ag. The magnitude of the ionic conductivity, as measured by diffusion in the solid increases from $AgNO_3$ to AgI and Ag_2S. Evidently the loosening of the lattice permits an increase in the speed of diffusion of the ions. The region of greatest diffusion is the region of greatest loosening, the region of a mixed, ionic-covalent bond; the rate of ionic diffusion begins to decrease when the intermediate type bond becomes predominantly covalent, and it decreases very rapidly from this point to the metallic bond. From F^- and I^- the ion becomes imperfect; the increase in deformation which at first accelerated ionic conductivity, finally reaches such a value that the imperfect ion *b* becomes an imperfect atom, probably in Ag_3Sb.

As ionic conduction, or diffusion, decreases from Ag_2Te to Ag, electronic or metallic conduction increases, again evidencing the transition toward the metallic bond (*122*).

In the region of extreme loosening of the lattice, the compounds are polymorphic, perhaps, to some extent, as a result of this loosened bond. There are two crystalline forms of AgI, Ag_2S, and Ag_2Te, and the transition from the ionic to the metallic bond seems to take place logically through these allotropic forms, as:

AgF	AgCl	AgBr	α AgI	α Ag_2S	α Ag_2Te			
I	I	I	I	I	I			
			β AgI	β Ag_2S	β Ag_2Te	Ag_3Sb	Ag_4Sn	Ag
			A	A	A	A	A	A

I = isotropic, ionic A = anisotropic, metallic

As a matter of fact, the electron conductivity of pure alpha Ag_2S is three hundred per cent. less than that of

beta Ag_2S (*123*). The transition from an ionic to a metallic bond through the loosened bond is, to say the least, suggestive. It is quite probable that this loosened state is somewhat akin to the metallic state. In the metallic state valence electrons are not held tightly by the atoms to which they belong. The metallic bond is essentially a modified covalent bond, in which electrons are held in common by the several neighbors of any atom, but because there are not enough electrons available to form stable electron pair bonds between any atom and all its nearest neighbors, these electrons are free to move about to some extent. They are held relatively loosely.

The degeneration of an anion may also be followed through the loosening of an ionic lattice and ionic bonds to the formation of a molecular lattice and covalent bonds, as shown in Table 51 (*122*). The transition from one extreme type to the other via a loosened lattice is evidenced by the high rate of vibration of the anion.

TABLE 51

THE TRANSITION FROM THE IONIC TO THE MOLECULAR STRUCTURE VIA THE LOOSENED BOND, AS MEASURED BY THE RATE OF VIBRATION OF CHLORINE (*122*)

NaCl	10^{-5} cm.^{2}	Ionic crystal. Ionic bonds.
$CdCl_2$, $PbCl_2$	10^{-3}	
$SbCl_3$	10^{-6}	
$AsCl_3$	10^{-7}	
Cl_2	10^{-16}	Molecular forces between Cl_2. Covalent Cl-Cl bonds.

PHOTOELECTRIC CONDUCTIVITY

Metallic, or electron, conduction in salts must depend upon electrons released from their usual participation in ionic or homopolar bonds. Marked photoelectric conductivity, therefore, may be anticipated for those crystal lattices in which electrons in the bond are already loosened. It is these electrons which may be loosened still further, under the influence of light, to the point where they take part in metallic conduction. Accordingly, the data in Table 52 are entirely in accord with what we should expect; the salts in which conductivity may be induced by light are those of B-cations and easily polarized anions, salts in which a non-ionic bond becomes influential.

TABLE 52

PHOTOELECTRIC CONDUCTIVITY OF SOME BINARY COMPOUNDS (B. GUDDEN AND R. POHL, *Z. Physik*, 16, 42 (1923))

	F	NO_3	SO_4	CO_3	Cl	Br	I	O	S
K	−	−	−	−	−	−	−	−	−
Na	−	−	−	−	−	−	−		
Ba	−	−	−	−	−				+
Sr	−	−	−	−	−				+
Ca	−	−	−	−	−		(−)	(−)	
Tl		−	−	+	+	+	+	+	+
Ag		−	−	+	+	+	+	+	+
Pb		−	−	+	+	+	+	+	+
Cu						(+)	+	+	+
Hg				(+)			+	+	+

PHOTOSENSITIVITY

Without question, the marked photosensitivity of the silver halides bears some relation to their loosened lattice structure. It is interesting to recall that ZnS, a part of lithopone, darkens on exposure to light, but regains its white color when kept in the dark. Various explanations have been offered for this phenomenon. In this case also the photosensitivity probably is related to a loosened, intermediate bond.

PROPERTIES OF NiAs AND FeS_2 STRUCTURES

Our discussion up to this point has been concerned chiefly with ionic crystals. It has been shown incidentally that molecular crystals are relatively weak, and in Table 36 the suggestion is given that crystals of the NiAs and FeS_2 structures are weaker, other things being equal, than ionic or covalent crystals. The crystals of this type are also insoluble in water, since they do not ionize readily. They are apt to be soft. Their metallic properties are striking; they tend to be opaque, with metallic luster, and perhaps most characteristic of all is their ability to dissolve an appreciable excess of either component. By their electrical properties they may be distinguished both from ionic and from metallic compounds. Their electrical conductivity is appreciable—which is not true of most ionic compounds. In contrast to metallic compounds, however, their conductivity increases rapidly with the addition of impurities; whereas, in a metallic compound the conductivity is a maximum when it is pure and decreases rapidly as impurities are added.

ATOMIC CRYSTALS OF BINARY COMPOUNDS

Normal covalent crystals—and it is by now apparent that there are very few among the inorganic binary compounds—are relatively strong, as measured by the standards set in this discussion, namely, hardness, melting points, solubility, and so on. SiC, TiC, ScN are typical examples.

SUMMARY

The influence of the structure of a crystal and of the size, valence, and electronic structure of its building stones upon some of the physical and chemical properties of binary compounds have been considered at length. These relationships which deal mainly with ionic crystals may be summarized briefly as follows:

1. Lattice energy, the measure of the tendency of an ionic crystal to break down into ions,
   (*a*) increases with decreasing size of the action,
   (*b*) increases with decreasing size of the anion,
   (*c*) increases with decreasing interionic distance,
   (*d*) increases with valence,
   (*e*) is greater for B-cation compounds than for those with A-cations.
2. Heat of formation, a measure of the tendency of a crystal to break down into atoms or molecules,
   (*a*) increases with increasing size of the cation,
   (*b*) increases with decreasing size of the anion,
   (*c*) increases with valence,
   (*d*) is greater for compounds of A-cations than for those of B-cations.
3. Compressibility, a measure of resistance to compression,

(*a*) is greater, the farther apart the ions or atoms in a crystal,
(*b*) is greater, the less close-packed the structure, the lower its coördination number,
(*c*) decreases as polarization or valence decreases,
(*d*) decreases as the influence of the covalent bond increases.

4. Hardness, a measure of the resistance to deformation,
(*a*) increases with decreasing interionic or interatomic distance,
(*b*) increases with valence,
(*c*) is greater for compounds of A-cations than for those of the B-cations,

5. Melting point, a measure of the resistance to disruption by heat,
(*a*) increases with decreasing size of the anion,
(*b*) varies irregularly with the size of the cation until corrected for the radius ratio effect,
(*c*) increases with valence,
(*d*) is greater for compounds of A-cations than for those of B-cations,
(*e*) is lower for layer lattices than for typical ionic lattices; and is lowest for molecular crystals,
(*f*) decreases as the number of anions per cation in the compound increases; that is, depends upon the crystal environment,
(*g*) is lower for the NiAs and FeS_2 structures than for ionic lattices, other variables being equal.

6. Solubility in water, a measure of the resistance of an ionic lattice to disruption by the hydration of its ions,
(*a*) increases, in general, with increasing size of the anions,
(*b*) increases frequently with increasing size of the cations; the correlation is not perfect,
(*c*) decreases with increasing valence of both ions in strictly ionic crystals, increases with increasing valence if layer or molecular lattices are formed,
(*d*) is less for compounds of A-cations than for those of B-cations if the anion is less easily polarized than water,
(*e*) is greater for compounds of *A*-cations than for *B*-cations if the anion is more easily polarized than water,
(*f*) is lower for layer and molecular lattices than for ionic lattices.

7. Hydrolysis, which is dependent upon the strong deformation of the hydroxyl ion, and the tendency to hydrolyze,
(*a*) increases with decreasing size of the cations,
(*b*) increases with increasing valence of the cation,
(*c*) is greater for the compounds of the B-cations than for those of the A-cations, because of the strong polarizing influence of the former.

8. Acidity and basicity.
(*a*) The acidity of a positive element increases as its attraction for electrons increases.
(*b*) Thus, other things being equal, a B-cation is less basic than an A-cation.

9. Properties of the "loosened" bond.

Certain properties characteristic of compounds of B-cations, or cations of the transition elements, with easily polarized anions, are best explained by the assumption that certain of the electrons have become more or less loosened. This tendency is manifested by the following properties of such compounds,
(*a*) color,
(*b*) conductivity by ionic diffusion,
(*c*) polymorphism,
(*d*) photoelectric conductivity,
(*e*) photosensitivity.

The foregoing summary refers principally to crystals with ionic or covalent-ionic bond. The influence of bond type upon the properties of crystals may be summarized briefly as follows:

1. *The ionic bond.*—Strength and related properties depend upon the size, valence, and electronic structure of the ions and, in many cases, upon the crystal structure.

2. *The covalent-ionic bond.*—These crystals are weaker, due to the "loosened" bond, except that they are more resistant to ionization and therefore less soluble. They tend to be colored and may be photosensitive.

3. *The covalent-metallic bond, the NiAs and FeS_2 structures.*—The properties are a mixture of those of the two pure types. They are usually less soluble, but otherwise weaker than ionic crystals. They bear a resemblance to metals, are apt to be opaque, and show a metallic luster and considerable metallic conductivity which increases with their degree of impurity. They can dissolve an excess of either constituent.

4. *The covalent bond in atomic crystals.*—The strength and related properties are apt to be greater than for ionic compounds, but of the same order of magnitude.

5. *The molecular bond.* These crystals are weak. They have low melting points. They are soft; their melts are non-conductors. They hydrolyze readily and are soluble in non-ionizing (molecular) solvents.

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PRESERVATION OF STARCH INDICATOR

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THE use of starch indicator in iodometry is well established, but the instability of the ordinary starch preparations has caused difficulties. Most textbooks and manuals of quantitative analysis recommend that the starch solution be prepared fresh just before use, or else that very cumbersome methods of sterilization and sealing be employed.

A very convenient and effective method, first recommended by Gastine,[1] has been generally overlooked by the textbooks of quantitative analysis. This method is as follows: 5 g. of a good grade of potato starch and 10 mg. of red mercuric iodide are intimately ground to a thin paste with a small amount of cold water. This paste is poured slowly into one liter of boiling water while stirring, and the whole boiled for two minutes. The solution is allowed to cool and separate into two layers. The clear upper layer is poured off or filtered through a fluted filter paper and is then ready for use. 2 ml. of this starch indicator is used for each 200 ml. of solution.

For individual student use, we fill 4-dram, cork-stoppered vials. The stock-starch solution is kept in large glass-stoppered bottles. This method has been in use in our laboratories for many years with satisfactory results.

A bottle and several vials of starch solution prepared in 1929 were recently tested in the following manner: 2.0 ml. of the starch was added to 200 ml. of distilled water. One drop (0.03 ml.) of 0.1 *N* iodine solution (13.0 g. iodine and 20 g. potassium iodide per liter of solution) gave a deep blue color. Likewise, 2.0 ml. of starch has added to 100 ml. of distilled water; 2.5 ml. of 0.001 *N* iodine solution produced a distinct blue color.

Hydrogen sulfide or sulfide ion does not affect the mercuric iodide.

[1] GASTINE, M. G., *Bull. Soc. Chim.*, **50**, 172 (1888).

A MODIFIED LABORATORY MANUAL RACK

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A. C. Adams[1] suggests the use of a wire coat hanger for the construction of a rack to hold a laboratory manual. His rack is illustrated in Figure 1. The author has found that the only serious objection to the use of this rack is the fact that heavy books tend to tip it over backward. However, if a supporting leg is provided for the rack by straightening the hook of the coat hanger and bending it back in the position (*A*) shown in Figure 2, a rigid support is provided for the book, and even such heavy volumes as Lewkowitsch's "Chemical Technology and Analysis of Oils, Fats, and Waxes" can be supported easily, without any danger of falling. The body of the rack may be made to extend a little higher by shortening the extended portion (*B*), which formed the support in Adams' rack.

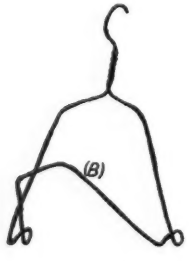

FIGURE 1

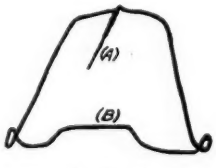

FIGURE 2

This type of book support also lends itself readily to use by stenographers, or others who desire a full-view holder for books, papers, etc. When the rack is used in this way, it is convenient to slip an ordinary cork over the end of the leg (*A*). This prevents scratching the desk or table top.

[1] ADAMS, A. C., J. CHEM. EDUC., **10**, 414 (1933).

MODIFIED HEMPEL GAS ANALYSIS APPARATUS ASSEMBLED *from* EVERY-DAY LABORATORY APPARATUS

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THE NECESSITY arose for the author to analyze flue gases in making some heating plant tests. No apparatus was at hand, so a modification of the Hempel apparatus was constructed from everyday equipment which may be found in any laboratory. The modified Hempel apparatus was very successful for the purpose intended. It was then applied to student use for the analysis and study of various gases such as automobile exhaust, air in rooms, cigarette smoke, etc. After learning to use the apparatus, students rarely made errors in analysis greater than one or two tenths of one per cent. The procedure with this apparatus is identical with that in which standard apparatus is used, with the exception of a detail or two which are given below.

APPARATUS

The Gas Buret.

This consisted of an inverted, 100-ml. buret with a three-way stopcock and side filling tube as shown in Figure 1, *A*. A simple, pinch-clamp buret could have been used, but the manipulation of gases was made easier with the three-way stopcock. The lower, open end of the buret was fitted with a one-hole rubber stopper, and a 250-ml. aspirator bottle with about three and one-half feet of rubber tubing was connected to this stopper to regulate the level of the liquid in the buret. The buret had to be calibrated to the zero point *B*, Figure 1, in order to calculate the per cent. by volume.

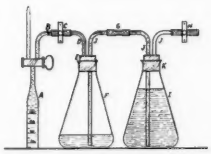

FIGURE 1.—MODIFIED HEMPEL BURET AND ABSORPTION PIPET

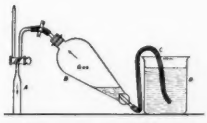

FIGURE 2.—SEPARATORY FUNNEL USED AS GAS SAMPLING TUBE

Modified Hempel Gas Absorption Pipet.

The modified pipet is shown in Figure 1 and includes all parts but the buret, *A*. *C* and *H* are screw clamps on $^3/_{16}$ inch, thin-walled rubber tubing and are used to regulate the level of the solution in the flasks and to keep out air when not in use. *D* is 1-mm. capillary tubing, although standard $^1/_4$-inch glass tubing could be used. This capillary tubing must not extend below the lower surface of stopper *E*. *E* and *K* are standard, two-hole rubber stoppers fitted to the flasks. *F* and *I* are 125-ml. Erlenmeyer Pyrex flasks. Absorption takes place in *F*, and *I* holds the solution displaced from *F* by the gas sample. The diagram shows the measured gas sample from the buret transferred to flask *F* in position for absorption of a constituent. *G* is a rubber tubing connection and *J* is ordinary $^1/_4$-inch glass tubing.

Gas Sampling Tube or Bottle.

A 250-ml. or a 500-ml. pear-shaped separatory funnel was used in storing gas samples for short periods or for collecting samples at a remote place from the analysis apparatus. The diagram, Figure 2, shows a separatory funnel sample tube in the act of transferring a sample of gas to buret *A* as indicated by the arrows. As the gas is drawn out of *B*, water from beaker *D* displaces the gas. This water is previously acidulated with about two per cent. H_2SO_4 and saturated with the type of gas used, as is that in the buret also. Instead of using beaker *D*, a second separatory funnel could be used clamped in an upright position, with the lower end connected to tube *C*. The beaker set-up is simpler, however.

To obtain a sample of gas in *B*, it is used in the ordinary way by connecting a glass or other tube to the top of the funnel in place of the buret as shown. With *B* full of water and the tube at the top inserted in the gas to be sampled, the lower stopcock is opened and the gas is siphoned into the funnel by displacement.

PROCEDURE

Except for the modifications noted hereafter the procedure for this modified apparatus is identical with that used for standard apparatus. Because the standard procedure and details of mixing the absorption solutions are available in practically all of the standard handbooks of quantitative analysis, they will not be described here.

Exceptions to Standard Procedure.

1. In filling the absorption pipet flasks, the stoppers

E and *K* of Figure 1 must not be allowed to become wet with alkaline solutions, for they will then become slippery and will cause trouble.

2. A standard pipet bulb is conical at the top, while the stopper *E*, Figure 1, is flat. For this reason one should avoid leaving any bubbles of gas in the flask when the sample is transferred over to the buret for measurement.

3. Absorption of the gas is carried out by shaking only flask *F*, Figure 1, about a horizontal axis *C-G*, instead of shaking the entire pipet as is done when the standard pipet is used.

CORRESPONDENCE

THE MAKING OF CRYSTAL LATTICE AND UNIT CELL MODELS

To the Editor

DEAR SIR:

Recently I had occasion to make some crystal lattice and unit cell models for exhibition in my classes in general chemistry. The models are so simple to make that they have captured the enthusiasm of the students who are now constructing them for ornamental as well as educational purposes. Because I have not seen them described elsewhere, I am sending a brief description to you in the hope that such models may prove of value to other teachers.

The models consist of assemblages of toy playing marbles (glass) cemented together by household cement (Duco). These materials can be obtained at the ten-cent stores. A close-packed arrangement of fifty to one hundred marbles is surprisingly strong if the marbles are cemented together at every point of contact. Close-packing of equal spheres is adequately described in the several excellent books on crystal structure (*1*, *2*) and the cementing together of marbles to give the possible lattices will be quite apparent to all interested in the subject. It is convenient to use a low cardboard box with one side cut away as a mold in forming the planes of a lattice. An interval of time should elapse before the second plane of the lattice is built up on the first plane.

The construction of a unit cell requires more ingenuity. The unit cell of a face-centered cubic lattice may be constructed as follows.

Six marbles are first cemented together at all points of contact. When this arrangement is dry, a seventh marble is cemented in place on top of the center of the triangle as shown (Figure 1). Two of these units are made.

When the units are dry, one is inverted over the neck of a wide-mouthed bottle so that the seventh marble projects into the bottle, and the plane of six marbles is level. Cement is applied to all possible points of contact, and the plane side of the second unit is dropped on to the upside down unit in such a position as to obtain a six-pointed star in two planes (Figure 2). When it is dry, this aggregate of fourteen marbles will represent a unit cell of the face-centered cubic lattice. By using pyroxylin lacquer and a fine brush, the (111) and other planes may be numbered on the unit cell.

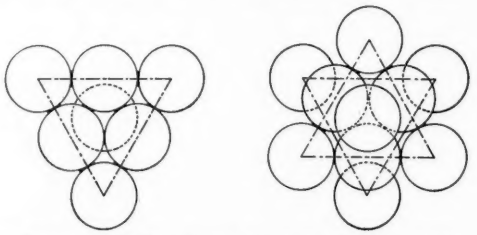

FIGURE 1 (*Left*).—SEVEN MARBLES CEMENTED TOGETHER AT ALL POINTS OF CONTACT TO FORM HALF OF A FACE-CENTERED CUBIC LATTICE UNIT CELL. THIS GROUP OF SEVEN MARBLES IS THEN CEMENTED TO ANOTHER SIMILAR GROUP

FIGURE 2 (*Right*).—A COMPLETED UNIT CELL OF THE FACE-CENTERED CUBIC LATTICE VIEWED LOOKING AT A CORNER. THE FOUR MARBLES IN THE THIRD AND FOURTH PLANES WHICH WOULD SCARCELY BE SEEN FROM THIS VIEW HAVE BEEN OMITTED IN THE DIAGRAM FOR CLEARNESS. THE TRIANGLES CONNECT THE CENTERS OF MARBLES IN THE SECOND AND THIRD PLANES

Planes may also be outlined by using different colored marbles. Such a unit cell may be built into a lattice of transparent marbles so that the cell itself may easily be seen. A number of these unit cells may be arranged together on a table to show how an extensive lattice may be built up. Tags may be attached to the models describing them and giving the elements which crystallize in the form shown.

Hexagonal close-packed unit cells may also be constructed. By using two colors of marbles, a sodium chloride lattice may be built up. Many other possibilities will suggest themselves.

Very truly yours,

ALLEN SCATTERGOOD

UNION COUNTY JUNIOR COLLEGE
ROSELLE, NEW JERSEY

(1) BRAGG, W. H., "The crystalline state," Oxford, the Clarendon Press, **1925**, especially pp. 144–6.
(2) MILLARD, E. B., "Physical chemistry for colleges," McGraw-Hill Book Co., Inc., **1936**, pp. 118–36.

LABORATORY EXPERIMENTS *for* UNDERGRADUATE ORGANIC CHEMISTRY

I. THE PREPARATION OF DIACETYLETHYLENEDIAMINE

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IT HAS often been a source of annoyance to teachers of organic chemistry that a larger portion of laboratory manuals than of textbooks is usually devoted to aromatic compounds. For this reason and also because of the industrial growth of aliphatic chemistry in recent years perhaps it might be well to find more aliphatic compounds suitable for preparation.

The preparation of diacetylethylenediamine (*N,N'*-ethylenebis-acetamide) has been found by us to be unusually satisfactory. It gives a fair yield of a very pure product in a reasonable length of time. It is, in fact, an experiment in the aliphatic series comparable to the preparation of acetanilide in the aromatic series. If it is regarded as an alternative to the preparation of acetamide by the heating of ammonium acetate, it has the advantage of requiring much less time and of giving more satisfactory results in the hands of students. Diacetylethylenediamine has been prepared by the action of acetic anhydride upon ethylenediamine,[1] by the action of ethyl acetate upon ethylenediamine,[2] and by the action of acetic acid upon ethylenediamine.[3] After experimenting in this laboratory with all three methods we have found that the last method is in every way the most satisfactory. Experiments with various methods of purification have convinced us that better results are obtained by crystallization from 95 per cent. alcohol than by any of the methods that have been proposed.[1,2,3] Ethylenediamine has recently been made available in commercial quantities at a reasonable price, and the other materials are among the cheapest substances used in the organic laboratory. If, however, one wishes to economize on materials, one half the stated quantities may be used with equally satisfactory results.

DIRECTIONS

Place 30 g. (30.6 cc.) of commercial 60–70 per cent. ethylenediamine* in a 200 cc. round-bottom flask and add 45 g. (42.9 cc.) of glacial acetic acid. The mixture will get hot and may boil. Attach the flask to a plain fractionating column. Fit the column with a cork holding a thermometer and connect the side-arm to a water-cooled condenser set downward for distillation. Use a graduated cylinder to receive the distillate, and heat the flask quite rapidly so that the distillate collects at a rate of about 1 cc. per minute. Continue the distillation until 23 to 25 cc. of the distillate has collected. This operation need not require more than twenty or thirty minutes. The temperature at the top of the column seldom goes much above 110°, but even if the temperature is allowed to rise considerably higher, it seems to have little effect on the purity or yield of the product. Cool the flask by placing it in cold water, and stir the contents with a glass rod to prevent the formation of a solid mass which will be difficult to dissolve for recrystallization. When the contents has solidified and the flask has cooled to near room temperature, add 55 cc. of alcohol, place the flask under a reflux condenser, and boil the contents until the product dissolves. When the solid material has dissolved, pour the solution into a 250-cc. beaker, place 5 cc. of alcohol in the flask, warm it and rinse it with the alcohol which should then be added to the solution in the beaker. Allow the solution to cool to room temperature. Finally cool the solution for some time with ice, if it is available, and filter off the crystals with suction. Wash them twice with enough ethyl acetate to cover them, filter, and place them between filter paper or porous tile plates to dry. When they are thoroughly dry, determine the yield and melting point. The yield is usually 25–35 g. The melting point should be near that of the pure substance which is 175.6°.[3,†] A few grams of slightly impure

[1] HOFMANN, A. W., "Notiz über Anhydrobasen der aliphatischen Diamine," *Ber.*, **21**, 2332 (1888).

[2] TUCKER, N. B., "Normal fatty acid amides of ethylenediamine," *J. Am. Chem. Soc.*, **57**, 1989 (Oct., 1935).

[3] CHITWOOD, H. C. AND REID, E. E., "Some alkyl-glyoxalidines," *ibid.*, **57**, 2424 (Dec., 1935).

* This product can be obtained from the Carbide and Carbon Chemicals Corporation, 30 East 42nd Street, New York City. The samples used by us had a specific gravity of 0.981 $\frac{20°}{20°}$ which indicates that it contained 68 per cent. ethylenediamine.[4] Therefore, the number of cubic centimeters of distillate to be collected and the theoretical yield of the product were calculated on the assumption that the ethylenediamine content of the commercial product was 68 per cent.

[4] WILSON, A. L., "New aliphatic amines," *Ind. Eng. Chem.*, **27**, 867 (Aug., 1935).

† Other melting points which have been reported are 173–173.5°,[2] 175°,[5] and 172°.[1] The melting point of the products obtained according to the above directions has usually been 172.5–174° corr.

product may be obtained by adding ether to the alcohol filtrate after crystallization. The theoretical yield should be based upon ethylenediamine, as acetic acid has been used in excess. Experiments have indicated that this practice yields a purer product.

The author wishes to express his appreciation for the aid of his organic chemistry students in testing this procedure.

[5] FRANCHIMONT, A. P. N. AND DUBSKY, J. V., "Sur l'acétylation de quelques acétamide substitutuées," *Rec. trav. chim.*, **30**, 184 (1911).

AIR-DRIVEN CENTRIFUGE FOR SEMI-MICRO QUALITATIVE ANALYSIS

WARREN C. VOSBURGH AND J. H. SAYLOR

Duke University, Durham, North Carolina

FOR separations in qualitative microanalysis for undergraduate students Engelder and Schiller (*1*) and Gerstenzang (*2*) have suggested the use of a hand centrifuge built for macro work. The authors in their course in qualitative analysis, which is carried out on a semi-micro scale, have used with success a number of air-driven centrifuges made in the laboratory shop by Mr. Fred Kuhn. The materials required are inexpensive, as most of them are stock materials. A diagram of the centrifuge is shown in Figure 1. A ball-bearing roller

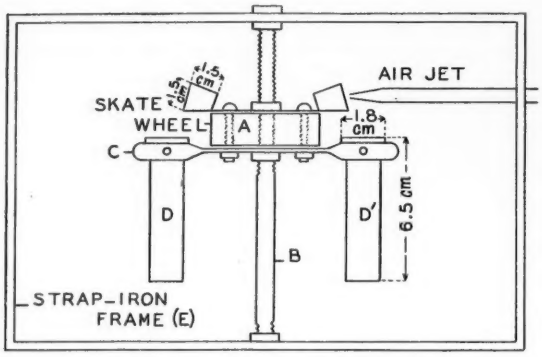

FIGURE 1.—DIAGRAM OF CENTRIFUGE

skate wheel *A* is mounted on a stationary vertical shaft *B* so that it rotates freely about the shaft on its own bearing. On the top of the wheel a six- or eight-blade fan is bolted and on the bottom a two-tube head, *C*, also shown in Figure 2. The head bears two brass rings *F*

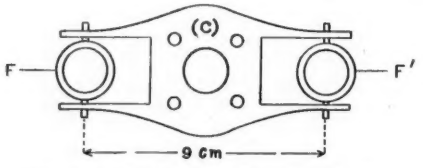

FIGURE 2.—DIAGRAM OF CENTRIFUGE HEAD

and *F'* (see Figure 2), which hold the aluminum tubes *D* and *D'*. The tubes *D* and *D'* were turned from 1.8 cm. (0.75 inch) aluminum rod and drilled with 1.3 cm. (0.5 inch) holes, which accommodate the 3-ml. glass centrifuge tubes used. Small holes were drilled through the bottoms of *D* and *D'* so that any liquid dropped in them is thrown out.

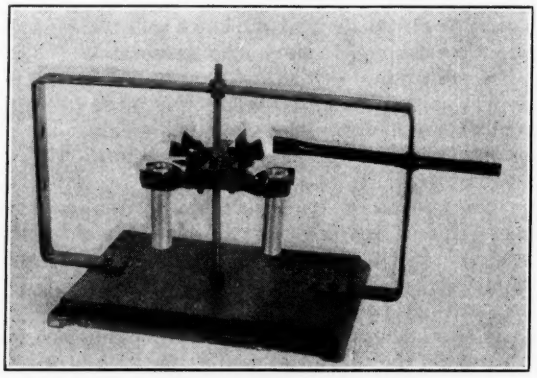

FIGURE 3.—PHOTOGRAPH OF CENTRIFUGE WITHOUT THE WOODEN PROTECTING FRAME

It was found that the use of a drawn-out glass tube for the air jet gave less noise in operation than the flattened copper tube shown in the photograph.

The laboratory compressed air is used to operate the centrifuges. The opening in the laboratory air tap was adjusted until the speed was such that the more difficult precipitates were thrown down satisfactorily in thirty seconds. At this speed, about 1000 R.P.M., the noise is not excessive.

For safety the centrifuges are surrounded by a square wooden frame. The strap-iron frame of the centrifuge (*E* in Figure 1) is fastened to the wooden frame by a rubber mounting made from rubber stoppers. The centrifuges have been used with entire satisfaction during three semesters and two summer sessions.

LITERATURE CITED

(1) ENGELDER, C. J. AND SCHILLER, W., J. CHEM. EDUC., **9**, 1638 (1932).

(2) GERSTENZANG, E. M., *ibid.*, **11**, 369 (1934).

EXPERIMENT *on a* TERNARY SYSTEM *of* LIQUIDS

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AN INTERESTING experiment in a laboratory course in physical chemistry can be done to illustrate equilibrium in a three-component system by determining the amount of one liquid necessary to make two immiscible liquids become miscible. Experiments of this kind are described by Davison and van Klooster[1] in which the amount of acetic acid necessary to make benzene-water mixtures miscible is determined and by Daniels, Mathews, and Williams,[2] using the system water-chloroform-acetic acid. The endpoints in these systems are rather difficult to determine, since the solutions must be made to change from clear to cloudy or cloudy to clear. The change is particularly difficult to determine in the benzene-water-acetic system when the percentage of acetic acid is high.

It has been the experience in this laboratory that the system nitrobenzene, water and acetic acid is very well adapted for a three-component experiment. The endpoint for this system is easy to detect since the nitrobenzene is colored and heavier than water. When the container is gently rotated, the small droplets of nitrobenzine, which are present as the equilibrium point is approached, are gathered in the bottom of the flask and can be watched as they disappear. As it has been worked out, the experiment consists in determining the amount of acetic acid necessary to make the following mixtures become miscible:

10 cc. of $C_6H_5NO_2$ plus 3 cc. of H_2O	2 cc. of $C_6H_5NO_2$ plus	5 cc. of H_2O
10 cc. of $C_6H_5NO_2$ plus 5 cc. of H_2O	2 cc. of $C_6H_5NO_2$ plus	10 cc. of H_2O
10 cc. of $C_6H_5NO_2$ plus 10 cc. of H_2O	2 cc. of $C_6H_5NO_2$ plus	20 cc. of H_2O
10 cc. of $C_6H_5NO_2$ plus 20 cc. of H_2O	2 cc. of $C_6H_5NO_2$ plus	40 cc. of H_2O
10 cc. of $C_6H_5NO_2$ plus 35 cc. of H_2O	2 cc. of $C_6H_5NO_2$ plus	60 cc. of H_2O
10 cc. of $C_6H_5NO_2$ plus 50 cc. of H_2O	2 cc. of $C_6H_5NO_2$ plus	80 cc. of H_2O
10 cc. of $C_6H_5NO_2$ plus 70 cc. of H_2O	2 cc. of $C_6H_5NO_2$ plus	120 cc. of H_2O

The initial mixture of nitrobenzene and water is placed in an Erlenmeyer flask and acetic acid added from a buret while the Erlenmeyer flask is rotated gently. At first the mixture is opaque, while at the equilibrium point the solution quickly becomes clear. Enough water is added to give the nitrobenzene-water proportions of the second mixture and the process repeated. In this way each series of mixtures is tested. As the amount of acetic acid increases, the change at the endpoint is less sharp, but it can be determined accurately by watching for the disappearance of the nitrobenzene droplets which collect in the center on the bottom of the flask. It is important that mixtures be thoroughly shaken to make sure all the $C_6H_5NO_2$ has been made miscible.

The amounts of acetic acid necessary at equilibrium have been determined in this way and the results are given in Table 1. The error involved in these readings is different for each mixture as given in the table because of the cumulative effect of the error of each reading. The greatest error of any one reading was ± 0.2 cc., and the greatest cumulative error was in the case of the mixture containing 10 cc. of nitrobenzene and seventy cc. of water. For this mixture it was ± 2.5 cc. of acetic acid. Thus, the worst error of individual measurements was 1.3 per cent. and the worst cumulative error was 1.52 per cent.

TABLE 1

$C_6H_5NO_2$		H_2O		CH_3COOH	
cc.	*Vol. %*	*cc.*	*Vol. %*	*cc.*	*Vol. %*
10	62.07	1	6.21	5.18	31.72
10	42.84	3	12.85	10.48	44.30
10	32.39	5	16.20	15.97	51.41
10	22.06	10	22.06	25.46	55.89
10	14.36	20	28.72	39.96	56.93
10	9.87	35	34.53	56.79	55.60
10	7.72	50	38.59	70.20	53.70
10	6.06	70	42.45	85.61	52.06
2	12.50	5	31.23	9.01	56.28
2	7.81	10	39.03	13.53	52.81
2	4.62	20	46.16	21.04	49.23
2	2.66	40	53.13	32.45	44.22
2	1.93	60	58.01	40.43	40.03
2	1.53	80	61.36	46.83	37.11
2	1.12	120	67.17	54.21	31.71

These results are plotted on the triangular diagram

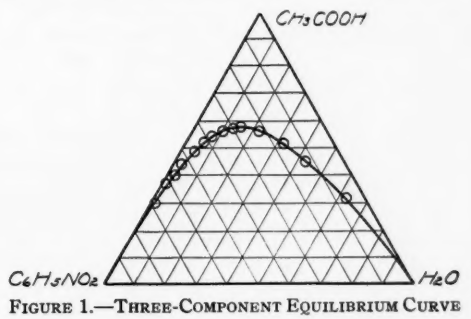

FIGURE 1.—THREE-COMPONENT EQUILIBRIUM CURVE

as shown in Figure 1. It should be noted that the mixtures as outlined give three overlapping points.

[1] DAVISON, A. W. AND VAN KLOOSTER, H. S., "Laboratory manual of physical chemistry," 2nd ed., John Wiley and Sons, New York City, **1931**, p. 104.

[2] DANIELS, F., MATHEWS J. H., AND WILLIAMS, J. W., "Experimental physical chemistry," 2nd ed., **1929**, McGraw-Hill Book Co., New York City, p. 106.

This is valuable in determining how well the curve may be drawn at the peak and gives a measure of the skill of the experimenter.

The value of the experiment is to a large extent dependent upon the ease with which students can duplicate the results. In order to determine this, the experiment was given to a group of fifteen seniors majoring in chemistry and to a group of fourteen pre-medical senior students. Of course, the former were more experienced in chemical technic, and thus a comparison between experienced and inexperienced students could be made. It was found that the experiment could be performed equally well by either type of student. The individual sets of data gave smooth curves when plotted, but there was a maximum variation in the cc. of acetic acid at the equilibrium points of about ten per cent. The cumulative variations were, however, only about this large and the final per cent. of acetic acid varied by a little more than five per cent. These variations were probably due to errors which occurred in measuring out the nitrobenzene. A small error here would result in a greater error in percentage when the measurement was made.

The last point which is of interest if the experiment is to be used in a laboratory group is the variation with temperature of the acetic acid needed to produce miscibility. Experiments showed an increase in temperature from 25°C. to 35°C. gave equilibrium values of acetic acid two per cent. higher. This change with temperature is small enough to make it a good experiment for comparison among a group of students who are working in conditions of varying temperature.

On the basis of the information given, it is felt that the experiment described is very satisfactory for use in experimental physical chemistry.

SUMMARY

1. An experiment illustrating equilibrium in a three-component system is described.

2. The correct values of each component present at equilibrium is given and tests cited to show that it is satisfactory for students to perform in the laboratory.

THE USE OF DENTAL TOOLS IN SOME LABORATORY MANIPULATIONS

C. S. MILLER

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FEW operations in the building of apparatus are so baffling as that of shaping a rubber stopper, so as to produce a neat and air-tight joint. It has been found by the author that a dental pick and an application of the principle of the lathe are most useful in this respect. A hole is drilled in the center of the stopper with an ordinary cork borer. The stopper is then placed on the shaft of a quarter-horsepower electric motor as shown in *A*. With a retort stand and bar as a rest, the stopper can now be cut with an old dental pick *B* sharpened to a long point, as the stopper rotates downward against the point. Some examples *C* and *D* of useful laboratory rubber products are shown. If a hole in the stopper is not desired it can still be turned by cutting the hole only part way through as in *E*.

It is also often desirable to cut a hole of some odd shape in a piece of apparatus, such as a hole in the side of a flask. A method which takes a little time, one half to one hour on the average, but which is very easy and produces an edge which does not crack readily, is by using a small dental grindstone. The glass is cut by simply holding it against the stone. This is an easy method of glass cutting and the glass is relatively free from danger of cracking while being ground. The size and shape of the hole can be governed much more easily than in the method of blowing. An adapter *X* for fastening the grindstone on an ordinary motor can be made at any machine shop for a few cents. The dental picks, grindstones, and mandrels can be obtained at any dental supply house, or from a local dentist. The stones *S* cost from five to ten cents each and the mandrels *M* cost about ten cents each.

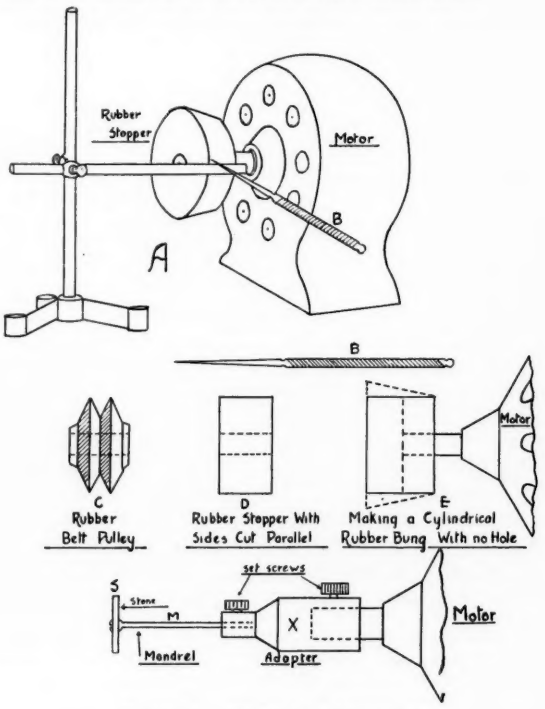

FIGURE 1.—DETAILS OF ASSEMBLY

W. O. Brooks
A. T. Burtsell
R. K. Carleton
Tenney L. Davis
J. Howard Graham
B. Clifford Hendricks
J. W. Howard

ABSTRACTS

R. A. Baker, *Abstract Editor*

D. C. Lichtenwalner
Greta Oppe

C. M. Pruitt
Leopold Scheflan
A. A. Vernon
E. D. Walter
Mary Elvira Weeks
Sidney Weinhouse
G. H. Woollett

KEEPING UP WITH CHEMISTRY

The economic importance of waste treatment to the industries. Michael J. Blew. *Ind. Eng. Chem., News Edition*, **14**, 445–6 (1936).—This is a summary of some of the ways in which waste treatment has been of benefit to industry. Paper mills screen waste to cut down pulp loss and use chlorine to prevent fungus growth. Treatment of waste water by a plant using photographic chemicals yielded three ounces of silver per ton of water, and the mud near the outlet of another plant assayed silver worth $170 from each ton. One mercerizing plant recovers ninety-seven per cent. of the caustic in the discharge water. A wool scouring plant installed a system to use the water from the end of the scouring train after treatment and this reduced water consumption by eighty-five per cent. A grease rendering plant cools the waste liquids and recovers enough grease to pay for the treatment. Laundries and hotels screen waste water and recover enough linen to pay for the process. A. A. V.

Tocco. Anon. *Ind. Bull. of Arthur D. Little, Inc.*, **117**, 3 (Oct., 1936).—Tocco is a new process for surface hardening of steel electrically. At present it is being used on crank shafts. The method is to pass low-voltage high-amperage current through inductor blocks surrounding, but not touching, the area to be surface-hardened. A current is induced in the surface itself, producing the necessary heat. G. O.

Utopian morsel. Anon. *Ind. Bull. of Arthur D. Little, Inc.* **117**, 4 (Oct., 1936).—This is an article telling of the methods used to "tenderize" tough meat. A recent patent covers the treatment of beef and other meat at the stock yards by forcing into the vascular system of the freshly killed stock a "tenderizing" fluid, thus making "the toughest of old range steer" tender. Nice questions are raised for the food inspector if this comes into practice. The tenderness of the smart restaurant's excellent beef has been obtained by the old art of hanging. Natives of certain tropical areas wrap freshly killed jungle meat or game in papaya leaves for a few hours before cooking because the papaya fluid softens or digests the proteins of the meat, "proteolytic enzymes." It is materials of the same type as these papaya enzymes that are being considered in modern food laboratories—pepsin and trypsin, for example. Already one product said to be an extract of papaya is being marketed to make tender steaks from cheap cuts. The liquid is painted on the meat five or ten minutes before cooking. G. O.

From the Chinese. Anon. *Ind. Bull. of Arthur D. Little, Inc.*, **117**, 2–3 (Oct., 1936).—The fusing of glass on gold was an art practiced by the Chinese. Although the exact origin of porcelain enameling is lost in antiquity, its progress can be traced through the centuries. Its advance left a trail of art objects as evidence of its improvement. Until comparatively recent years, porcelain enameling remained one of the fine arts. Its use was restricted to miniature objects, portraits, and curios. A little over one hundred years ago an enterprising German produced enamel pots and pans. The scene shifted to England and Scotland. Bath tubs lifted porcelain enameling into the ranks of developing industries. The scarcity of ceramic engineers and the lack of research in chemistry left a costly burden on those who tried to practice it. But through the years all these difficulties were overcome, and in 1929 when so many industries collapsed, porcelain enamelers went into fierce business competition. Electric refrigeration, washing machines, and ranges turned to porcelain. Porcelain's most recent adaptation has been in architecture. Service stations, store fronts, office buildings, homes, and restaurants offer interesting opportunities. G. O.

Microchemical analysis. Fred C. Mabee. *Rept. New Eng. Assoc. Chem. Teachers*, **38**, 34–8 (Sept., 1936).—Microchemical analysis has been developed in recent years because of a genuine need for a technic capable of analyzing very small samples of material, *e. g.*, in biochemistry (enzymes, hormones, and vitamins), industry and medico-legal work (poison cases). The two leading pioneers in this development were Professor Emich of the Technische Hochschule, Graz, Austria, and Professor Fritz Pregl of Graz. Their best books in English describing their methods are "Microchemical Laboratory Methods" (Emich) and "Quantitative Organic Microanalysis" (Pregl). Qualitative microanalysis has the following advantages: economy in cost of reagents, less space required in storing reagents, less fumes of hydrogen sulfide, etc. Such a method of instruction in analysis has been in vogue for several years at McMaster University, Hamilton, Ontario (Professor Walker) and at the University of Pittsburgh (Professor Engelder). Dr. Benedetti-Pichler teaches a course at Washington Square College, New York University, on general microchemistry. He states that the smallest sample practicable at present is 0.0001 milligram. The usual micro sample is 1 to 5 mg. For very small samples one should let the reactions take place in capillary tubes and use a lens or microscope to observe the precipitates and colors.

The essential instrument for quantitative microchemical analysis is the microchemical balance. This instrument was developed in the first place by W. F. Kuhlmann of Hamburg at the request of Professor Pregl. Kuhlmann's careful grinding of the knife-edges increased the sensitiveness from 0.01 mg. to 0.001 mg. The beam has a length of only 70 mm. The maximum load for the balance is 20 g. The balance is provided with a rider adjustment carrying a lens, and hooks on the left bow for carrying absorption apparatus.

Applications of microanalysis are (1) industry, *e. g.*, determination of small amounts of metals in canned vegetables and fruit, (2) medicine and biochemistry, *e. g.*, Folin-Wu microchemical determination of glucose in blood; 0.1 cc. of blood is withdrawn from the ear and twelve to fifteen minutes are sufficient for the analysis, (3) research, *e. g.*, ultimate analysis of organic compounds like vitamins, drugs, or compounds recently discovered, where only a very small amount is available, and yet the percentage composition must be determined with precision in order to get the constitution.

Courses in quantitative microchemical analysis are given in the following eastern institutions: Cornell, Columbia, New York University, and New Hampshire State University. W. O. B.

An accurate and easily made balance. R. D. East. *Sch. Sci. Rev.*, **18**, 132–5 (Oct., 1936).—Detailed directions are given for the construction of a balance, sensitive to 0.01 g., range 0–200 g. at a cost of about fifty cents. All parts are made of sheet aluminum, and ordinary razor blades are used as knife-edges. S. W.

Properties of silicate paints for concrete. Anon. *Chem. Industries*, **39**, 511 (Nov., 1936).—The question of paints is one of vital interest, especially in view of the rapid and enormous increase in the construction of concrete and cement walls.

Cement necessitates a very special paint which must approach as closely as possible that of the surface which is to be painted in order that as much homogeneity as possible is obtained between the paint and the covered surface.

For this purpose, specialists have developed paints with a basis of liquid silicates, in many cases potash silicates.

Relatively the cost of these paints is not very high, as their use presents no difficulty, and they have definite advantages. The hardness of this newly developed paint increases as time passes, due to the prolonged action of CO_2 of the atmosphere on the silicate. The silicate usually sold in the trade is a composite

varying between a disilicate and a tetrasilicate which, under the action of the CO_2 of the air duplicates itself in a hydrated potash carbonate and in an amorphous silicate.

$$K_2O, 4SiO_2 + CO_2 = K_2CO_3 + 4SiO_2$$

A part of the amorphous silicate partially crystallizes in the form of a colloid silicate which recombines itself later with the potash carbonate to result in a monosilicate:

$$K_2CO_3 + SiO_2 = K_2SiO_3 + CO_2$$

The excess in silicate stays in an amorphous state and forms a very resisting vitreous cement. The layer of silica effectively protects against water and outside corrosions and gives to the mass properties of impermeability. The silicate brings about perfect incombustibility to inflammable materials; owing to the formation of a vitreous layer, colors are protected against action of disturbing agents and, as a result, the brightness and the freshness of these paints resist the destructive influence of atmospherical agents for a long time. A. T. B.

The magnetic method of producing ultra-low temperatures. L. L. QUILL AND R. F. ROBEY. *Sch. Sci. Math.*, **36**, 871–85 (Nov., 1936).—Apparently there is no limit to how hot bodies may become, but in the matter of low temperatures theory dictates the limit as −273.18°C. The attainment of such a limit constitutes an immediate challenge to the scientist. Onnes has reached a temperature of 0.82°A. by boiling liquid helium under very low pressures. Keesom, using diffusion pumps of capacity fifteen times greater than those of Onnes, obtained solid helium at a temperature of only 0.11° less than that obtained by Onnes. The first theoretical discussions relative to the production of temperatures below 1°A. by the utilization of the magnetic properties of certain paramagnetic substances were published almost simultaneously by Debye at Leipzig and Giauque at California. They pointed out that when a magnetized body is demagnetized adiabatically, the temperature of the body must decrease. A body which is capable of being magnetized and which is in contact with a bath of liquid helium (1.26°A.) contains a great number of small elementary magnets in a random arrangement. When the body is placed in a magnetic field all of these magnets, or dipoles as they are often called, are oriented. Some order is brought to the original random arrangement. At present only three laboratories of the world are equipped for the study of low temperatures produced by the magnetic method, those of W. F. Giauque at the University of California, F. Simon and N. Kürti at Oxford University, and W. J. deHaas at the University of Leyden. The author draws a typical apparatus and describes it. Whether or not certain substances which are paramagnetic at higher temperatures become ferromagnetic below 1°A. is a problem which is yet to be investigated. deHaas in *Nature* has stated that he is convinced that the theoretical low temperature limit can be reached. What would happen to our concept of temperature and the absolute zero one might only guess. Would it be necessary to reset the zero point at a lower value? J. H. G.

Resistance of solid surfaces to wetting by water. R. N. WENZEL. *Ind. Eng. Chem.*, **28**, 3, 988–94 (Aug., 1936).—The application of wetting theory to the study of water-repelling agents and the description and use of an improved apparatus, using the contact angle measurement principle, are discussed. The comparison of water repellency imparted to paper and textile surfaces by dilute waterproofing baths as well as the results of the work on waxes, gums, and metallic soaps are presented. It was found that adhesion tension, in terms of characteristic interfacial tension values, is not a direct measurement of wettability since the latter depends on the physical conditions of the surface. The amount of surface per unit area of fibrous material and the nature of the deposit itself are important factors in the effectiveness of waterproofing agents. D. C. L.

Chemical structure of lubricating oils. L. A. MIKESKA. *Ind. Eng. Chem.*, **28**, 8, 970–84 (Aug., 1936).—Why oils lubricate has been a puzzling question which is attacked here from the synthetic viewpoint. Series of hydrocarbons have been prepared and a relationship has been established between viscosity and chemical structure. The effect of length, unsaturation, and branching of side chains on alkyl derivatives of benzene, naphthalene, and diphenyl have been studied. The work of previous investigators is summarized. Fifty-two different compounds are listed with various physical properties. In short, it is found that:

(1) for hydrocarbons of a given molecular weight, the greater the complexity of the ring, the higher the viscosity; (2) a long paraffinic side chain is more effective in increasing the viscosity index of a given hydrocarbon than a corresponding number of carbon atoms divided among two or more side chains; (3) the viscosity increases with the number of side chains if the number of paraffinic carbon atoms attached to a given nucleus remains unchanged; (4) for a given number of carbon atoms, straight chains are more potent in increasing the viscosity index than are branched chains; (5) an olefinic linkage in the side chain invariably decreases the viscosity but has a small and irregular effect on the viscosity index; (6) in general, long straight chains make for higher melting points than corresponding branched chains. D. C. L.

Pontalite. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **118**, 3 (Nov., 1936).—Pontalite is the latest of the transparent plastics. Chemically it is organic glass, methyl methacrylate, the methyl ester of methacrylic acid. It shares the lightness of the urea-formaldehyde, vinyl, and styrol types of plastics, but exceeds them in transparency and brilliancy. In addition to its clarity, this resin has a high softening temperature, high tensile and impact strength, good dielectric properties, good ultraviolet transmission, and, although it is softer than glass, it is more surface-resistant. Due to its unusual clarity, it can be combined with varying amounts of dyes and pigments. It may be used as a substitute for glass if strength, lightness, ultraviolet transmission and ease of fabrication are desired. G. O.

Spectrum analysis. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **118**, 3–4 (Nov., 1936).—This article tells of the use of the spectroscope in production of chemicals, medicinals, foods, and metallurgical products. The history of the spectroscope is briefly traced from the time of Sir Isaac Newton in 1666 when he observed a beam of light breaking up into the various colors by means of a prism. Spectroscopes were originally designed for visual observation of the spectrum, and many changes have been made in the spectroscope itself. The flame, the electric arc, and the electric spark are the most common light sources. Spectroscopic analysis is of two types, emission studies and absorption studies. The spectrograph has been used to advantage to determine metals in foods, beverages, and cosmetics. It is an admirable tool to show the presence of metallic poisons in body tissues. One of the coming developments in spectroscopy is a device which will indicate the percentages of various substances in an alloy or ash. The elimination of photographic methods and the substitution of photo-cells will make this possible. An installation of this type would be invaluable for the classification of alloy steel and other metal scraps. G. O.

Chemurgy spreads southward. EDITORIAL STAFF. *Chem. & Met. Eng.*, **43**, 582 (Nov., 1936).—A chemurgic council was held recently in Louisiana. It was backed by sugar, tung oil, cotton, naval stores, rice, and other southern farm organizations which are interested in securing new uses for their products.

Pointed out as profitable products which may be made from sugar or molasses by various fermentation processes are ethyl alcohol, acetone, butanol, butyric acid, and citric acid.

The bagasse from the sugar cane has been used for several years as a structural insulating material (celotex). It is now believed it will be the basic material in other industries as well. Possible by-products from rice, sweet potatoes, wood pulp, naval stores, tung oil, and soybeans were also discussed.

The wonderful combination of fuel, power, labor, and raw materials found in the South is making it a great chemical area. J. W. H.

Gas industry trends. R. S. MCBRIDE. *Chem. & Met. Eng.*, **43**, 602–3 (Nov., 1936).—Gas engineering is again attracting more attention from technical men.

The demand for natural gas has become so great that it will be necessary to do further exploration and deeper drilling for gas in proved areas or return to large scale water-gas production.

The affiliation of utility enterprises with natural gas is emphasized by their common interest in marketing of bottled liquefied petroleum gases.

Many studies are being made of the blending of low-volatile and high-volatile coals for manufacture of coke and coal gas.

An outstanding new industrial application of gas is its use in air-conditioning units.

A large number of new types of control devices for the use of gas have been developed. J. W. H.

Repression of ionization by a common ion. L. S. GUSS. *Sch. Sci. Math.*, **36**, 888–9 (Nov., 1936).—The law of mass action enters into many of the reactions of elementary qualitative analysis. Most of our separation procedures by precipitation depend on the repression of ionization by a common ion. A common example is the precipitation of the iron family of metals

by ammonia. Ammonium hydroxide ionizes slightly to liberate OH^- ions:

$$NH_4OH \leftrightharpoons NH_4^+ \text{ plus } OH^-$$

Normally there are sufficient hydroxide ions present to precipitate not only the iron, aluminum and chromium ions, but many others, notably magnesium. We are told, therefore, to add ammonium chloride, which by ionization yields ammonium ions:

$$NH_4Cl \leftrightharpoons NH_4^+ \text{ plus } Cl^-$$

The common ion represses the ionization of the ammonium hydroxide to such an extent that there are insufficient hydroxide ions to precipitate magnesium hydroxide. Such an explanation, although correct as far as the principles involved are concerned, always raises questions in the minds of thinking students. The author, in elucidation, emphasizes the greater attraction of the ammonium ion for hydroxide ion as compared to the lack of attraction of other positive ions such as potassium and sodium, for the hydroxide ion. This explains why only weak electrolytes can have their ionization repressed by a common ion. The ions must have an attraction for one another if the addition of a common ion is to repress their dissociation. J. H. G.

Carbon monoxide as a chemical raw material. N. W. KRASE. *Chem. & Met. Eng.*, **43**, 590–5 (Nov., 1936).—Carbon monoxide is classed as a "secondary" raw material because it is a by-product of industries using primary raw materials. It may be made from such carbonaceous materials as coal, coke, petroleum, natural gas, or from the oxides of metals.

Carbon monoxide may be separated from gas mixtures by absorption in acid or ammoniacal solutions of cuprous salts. The absorption takes place at about room temperature in packed towers at elevated pressure. The solution is then heated to 40–50°C. under partial vacuum and the evolved carbon monoxide is purified and dried.

Carbon monoxide may be combined with metals and ores to form carbonyls, with water and alkalies to form formic acid and formates, with hydrogen to form alcohols, acids, aldehydes, ketones, and hydrocarbons, with aliphatic hydrocarbons to form ketones and acids, with hydroaromatic hydrocarbons to form ketones and aldehydes, with olefins to form acids and esters, with aliphatic alcohols and ethers to form acids and esters, with ammonia to form amides and cyanides, and with chlorine to form phosgene. J. W. H.

The chemistry and manufacture of synthetic acetic acid. O. ZAHN. *Chem. Industries*, **39**, 493 (Nov., 1936).—After the World War demand for acetic acid increased, owing to the introduction of acetate rayon and other materials produced from acetyl cellulose, and consequently large-scale plants for the manufacture of synthetic acetic acid are today in operation in all industrial countries.

In all these plants, acetic acid is produced from acetylene in two distinct operations; first, the hydration of acetylene to acetaldehyde

$$C_2H_2 + H_2O = C_2H_4O$$

and, second, oxidation of the acetaldehyde to acetic acid

$$C_2H_4O + O = C_2H_4O_2$$

Formation of acetaldehyde by the addition of water to the acetylene molecule was first published by Kutscheroff in 1881 and was confirmed in 1898 by Erdmann and Köthner, who recognized that it is a catalytic reaction which proceeds in the presence of mercury salts. K. A. Hofmann at the same time carried out investigations with a view to clearing up the reaction.

Although the oxidation of acetaldehyde to acetic acid may appear to be quite a simple process, especially when oxygen is being used, the operation nevertheless calls for certain precautionary measures and a great deal of experience. Peracetic acid, which is explosive, is first formed by the oxidation:

(1) $CH_3COH + O_2 = CH_3CO_3H$
acetaldehyde — peracetic acid

(2) $2CH_3CO_3H \text{ heating} = 2CH_3COOH + O_2$
peracetic acid — acetic acid

(3) $2CH_3COH + O_2(\text{set free from 2}) = 2CH_3COOH$
acetaldehyde — acetic acid

In order to eliminate the risk of explosion as far as possible, the oxidation must always be carried out within a temperature range of from 20 to 80°C. Reaction vessel must be capable of being cooled, as well as heated. Oxidation is best kept under control by diluting the acetaldehyde, for which purpose the most suitable diluent is the concentrated acetic acid that is formed. Oxidation can be carried out either continuously or at intervals; a small quantity of the reaction mixture dissolved in the acetic acid will always be left behind in the reaction vessel.

Methyl acetate, water, and formic acid are formed as by-products. When 99.5 per cent. oxygen is used, the composition of the reaction product is approximately:

Acetic acid	97–98%
Methyl acetate	1–2%
Water	1–2%
Formic acid	0.2–0.5%
Acetaldehyde	traces

This yield is about 95 per cent., both in the hydration process as well as in the oxidation process.

The production of acetaldehyde and acetic acid is attended with danger. Tendency of acetylene to explode is well known; acetaldehyde is very flammable. In the presence of small quantities of acids or bases, acetaldehyde tends to polymerize with a considerable evolution of heat. Mercury can only be handled with suitable precautions from a hygienic point of view. Decomposition of any large quantity of peracetic acid takes place explosively. A. T. B.

Chemistry in the printing industry. B. L. WEHMHOFF. *Ind. Eng. Chem., News Edition*, **14**, 417–8 (1936).—Letterpress printing is done from relief type plates in which all printing areas are raised above the remainder of the form. Intaglio printing is done from a cylinder in which all printing areas are recessed, while planographic printing is done from a plane surface. All three processes are based on chemical reactions, and a chemist is able to help control many variables which affect the finished product. Type is cast from a lead-tin-antimony alloy, and chemical control of the proportions of the alloys, as well as removal of impurities such as zinc and copper, is necessary. Electrotype plates are made by molding the form from the type with wax. The mold is then rendered electrically conductive by graphite and copper deposited upon it. The deposit is then backed with lead-tin-antimony alloy and shaped to thickness and form. The wax must be uniform and the electrical deposition well controlled. Intaglio plates are electrically deposited sheaths of copper on metal cylinders. The copper is subsequently treated to produce a printing surface. Thus, all steps in the preparation of plates involve chemical reactions. The basis of all printing, once the plates are made, is ink and paper. It is the function of the printing plant chemist to make tests to insure that the ink used will have the correct shade and drying qualities and be suited for the paper to be used. Binding materials are purchased on chemical specifications and research is in progress to develop new flexible bindings which will be serviceable in both winter and summer. It is concluded that there are many possibilities for savings through research on printing and binding. A. A. V.

Manufacture of glass—II. M. PARKIN. *Sch. Sci. Rev.*, **18**, 9–19 (Oct., 1936).—A description of technical processes in the manufacture of sheet glass, bottles, lamp bulbs, etc. S. W.

APPARATUS, DEMONSTRATIONS, AND LABORATORY PRACTICE

Acids occurring naturally in fruits. J. W. NECKERS AND T. W. ABBOTT. *Sch. Sci. & Math.*, **36**, 986–92 (Dec., 1936).—In recent years considerable stress has been placed in the field of dietetics on alkaline and acid "ash" produced during the metabolism of foods. "Acidosis" has been a semipopular word to explain vague maladies, but it is a term of great biochemical significance. In general, various fruits produce an alkaline ash. Not since 1917 has a summary been made of the research determining the organic acids present in fruits and vegetables. In the last eighteen years there have been a number of contributions to the knowledge in this field. A summary of the findings to date is given in the following data.

Malic acid: apples, apricots, bananas, blueberries, cherries, cranberries, currants, figs, gooseberries, grapefruit, grapes, lemons, loganberries, peaches, pears, persimmons, pineapples, plums, prunes, quinces, raspberries (red), strawberries, watermelons, and whortleberries.

Citric acid: apples, apricots, blueberries, canteloupes, cher-

ries, cranberries, currants, figs, gooseberries, grapefruit, lemons, loganberries, mulberries, peaches, pears, pineapples, pomegranates, prunes, raspberries, strawberries, whortleberries.

Oxalic acid: apples, apricots (?), blackberries, cherries, currants, figs (dried) grapefruit.

Boric acid: dates, figs (dried), peaches (dried), prunes, raisins.

Tartaric acid: apricots, grapes, grapefruit, prunes, raspberries (black).

Succinic acid: apples, blackberries, cherries, currants, mulberries.

Benzoic acid: cranberries, plums, prunes.

Lactic acid: apples, cherries.

Quinic acid: cranberries, whortleberries (?).

Acetic acid: figs, peaches.

Levulinic acid: quinces.

Isocitric acid: blackberries. J. H. G.

Microvaporimetric determination of molecular weight. J. B. NIEDERL, O. R. TRAUTZ, AND A. A. PLENTL. *Ind. Eng. Chem.*, **8**, 252–5 (July, 1936).—A few milligrams of a substance is vaporized in a closed system in such a way as to permit an accurate indirect volume determination for a temperature range of 300°C. Hg, the sealing fluid, is displaced instead of air. In the diagram, *F* is a round-bottomed Pyrex flask, about 350 cc. capacity *C* is a condenser, *T* a thermometer. The Pyrex glass vaporimeter, *V*, consists of the egg-shaped vaporizer *B* of 12 to 15 cc. capacity and hollow stem *S*, 11 cm. long, and inner diameter 6 mm. *J* is a hollow ground glass joint and *R* is a centrifuge tube of 15 cc. capacity which serves as receiver. *V* is fused into the flask *F*. (This apparatus may be purchased ready-made.) The sample is introduced in a capillary, weighed to 0.001 mg. The sample used is about 8 mg. If it is solid it is melted first. The sample is introduced into the apparatus, which is then filled with purified Hg to the very tip, and the heating liquid put into the outer bath. The temperature is noted and the heating carried on rapidly until the boiling point is reached and again noted. The Hg is weighed and corrections made for the expansion of Hg due to temperature. A blank can be run to measure this expansion. Detailed directions for calculations and correction for change in *P* due to the Hg are given. This method, in addition, permits repetition as well as simultaneous observation of the boiling and condensation point on a single sample. D. C. L.

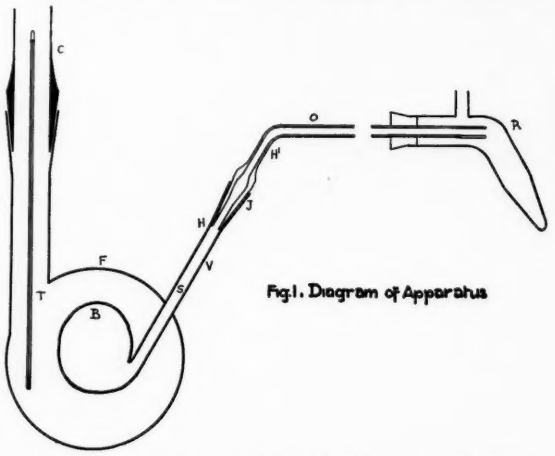

Fig. 1. Diagram of Apparatus

Courtesy of Industrial and Engineering Chemistry

SCIENTIFIC REVIEWS AND BIBLIOGRAPHIES

What becomes of chemical engineers? ANON. *Chem. & Met. Eng.*, **43**, 645–6 (Dec., 1936).—This survey was made by the United States Bureau of Labor Statistics and covered all branches of the engineering profession. Its primary purpose was to find out how engineers had fared during the depression. A total of 52,589 engineers supplied data for the survey. They were grouped into nine major professional classes. 3926 were listed as chemical, ceramic or mining and metallurgical engineers. These were grouped together as "chemical engineers." They were found to be in the following fields of activity, 56.6 per cent. in manufacturing, 21.4 per cent. in the extractive industries, 9.4 per cent. in personal service, 8 per cent. in government, 3.2 per cent. in public utilities, and 1.5 per cent. in construction. Under a functional classification it was found that 46.3 per cent. were in operation, 27.6 per cent. in design and research, 6.8 per cent. in teaching, 6.7 per cent. in consulting, 6 per cent. in administration, 3.9 per cent. in construction.

The educational data made available by the survey showed that among chemical engineers 95 per cent. had taken their first degrees in chemical engineering, which indicates other engineers are not shifting into chemical engineering work in great numbers. Only a very small proportion of chemical engineers are without a college degree. The chemical engineer spends a greater average number of years in college than any of his professional brothers. J. W. H.

HISTORICAL AND BIOGRAPHICAL

Victor Grignard, 1871–1935. ANON. *Nature*, **138**, 791 (Nov. 7, 1936).—The life and work of Professor Victor Grignard, who died on December 13, 1935, has been described by Professor Ch. Courtot of Nancy in the *Bull. Soc. Chim.*, **3**, 1433 (1936). Professor Grignard was best known for his syntheses by means of the organo-magnesium compounds. He became professor of organic chemistry at Nancy in 1910 and of general chemistry at Lyons in 1919. Shortly before his death he commenced a large treatise on organic chemistry, two volumes of which appeared during his lifetime. M. E. W.

Discovery of positron one of science's great events. WATSON DAVIS. *Sci. News Letter*, **30**, 324–5 (Nov. 21, 1936).—In 1931 Dr. Carl D. Anderson at the California Institute of Technology found that cosmic rays disrupt atoms of air and other matter as they plunge earthward. By photographing cosmic ray tracks in an expansion chamber he studied these effects. One such exposure revealed a path which was made by a positive particle which he, at the time, inferred to be a proton. However, he continued photographing such effects, using many feet of film until on August 2, 1932, he found a particle which "left a water droplet trail five centimeters long even after it plunged through six millimeters of lead. After carefully checking its curvature .... and digging into the Dirac electron theory (postulating the existence of a positive electron) Dr. Anderson concluded that the positive electron had been caught." He did not report his find, however, until two more similar observations had been made. After he had reported his discovery he continued photographing cosmic ray fog tracks until he had fifteen confirmations of his first find. In February, 1933, his discovery was confirmed by P. M. S. Blackett and G. Occhialini in the Cavendish Laboratory, Cambridge, England. Thus was the research accomplished which brought Dr. Anderson a share of the 1936 Nobel prize for physics. B. C. H.

Pioneer maker of coal-tar chemicals. ANON. *Chem. Industries*, **39**, 355–60 (Oct., 1936).—Of all that sturdy band of rugged individualists who during the past century founded our great American chemical companies, none was so incorrigible an independent, so indomitable a fighter as John Francis Queeny, founder of the Monsanto Chemical Company. With his background of experience and acquaintance in the wholesale drug trade, it was not unnatural that he should select the fine and medicinal products of coal-tar origin when he determined to become a chemical manufacturer. He must have been aware of the technical difficulties involved in the manufacture of this complex group. He knew perfectly well that this was the chemical domain which the powerful German companies had made their own

and which they were determined to dominate. As a buyer he was quite familiar with the ruthless methods they had long successfully employed to prevent the establishment in this country of any domestic production of coal-tar dyes, coal-tar aromatics, and coal-tar medicinals. He had first-hand information on the comparatively limited market for the chemicals he proposed to produce; and he was amply forewarned of the negative, but stubborn, sales resistance which any newcomer would meet in this comparatively new medicinal field from exacting demands for purity and the extreme conservatism of buyers. It would almost seem that Mr. Quenny had deliberately picked out the most difficult of all chemical fields and the one in which success would be longest delayed even under the most favorable circumstances. Courage was one of his most outstanding characteristics. A. T. B.

The evolution of the concept of allotropy. S. T. BOWDEN. *Sch. Sci. Rev.*, **18**, 28–31 (Oct., 1936).—Since the idea of allotropy first took root it has suffered many vicissitudes and modifications. The first observation of the transformation of a solid element into another solid state was made at a very remote period. Both Aristotle and Plutarch were familiar with the crumbling of tin articles ("tin pest"). Toward the end of the eighteenth century, Lavoisier recognized carbon as an element and again met with it in the diamond, which he was able to convert completely into carbon dioxide. When later it was recognized that compounds of the same composition may possess different chemical properties (isomerism) and that compounds chemically identical can appear in different crystalline forms (polymorphism), the way was prepared for the general acceptance of the idea that a chemical element can also appear in different modifications. In 1841, after several more observations of the phenomenon, Berzelius introduced the term allotropy.

The break from the traditional restriction of the term to the behavior of elements was initiated by Ostwald, who included under the general term allotropy the transformation and transition phenomena of both elements and compounds. S. W.

Joseph Black, M.D. (1728–1799). E. W. J. NEAVE. *Sch. Sci. Rev.*, **18**, 45–9 (Oct., 1936).—Joseph Black was Professor of Chemistry at Glasgow (1756–66) and at Edinburgh (1766–99). His thesis, submitted for the M.D. degree at Edinburgh in 1754, was entitled, "Experiments on Magnesia Alba, Quicklime, and some other Alcaline Substances." Before Black gave the correct explanation of the relationship between chalk and lime, the prevailing theory was that of Boyle: "the calcareous earth (chalk) when burnt to quicklime, receives some subtile and active principle, communicated to it by the fire or heat." Black pointed out that the existence of the active principle had never been demonstrated, and instead of receiving an addition, there was a considerable loss. The result of Black's research, based on quantitative measurements, was that the difference between chalk and lime, as between caustic and mild alkalies, was due to "fixed air" (carbon dioxide). His work, according to Ramsay, "brought his name before every philosopher in Europe and America as that of a man who had made a discovery of more fundamental influence on the progress of chemistry than any which had been previously described."

In addition to his purely chemical contributions, Black was the first to place the doctrine of latent heat on a sound quantitative basis. The figure which he obtained for ice (81 cal./g.) is very nearly the accepted value of today. His success in his investigations was greatly assisted by consistent use of the balance; he considered that observations were not complete until reduced to a quantitative form.

Black continued at Edinburgh until his death in 1799. In 1803 his lectures were published from his manuscript notes as "Lectures on the Elements of Chemistry." This work, edited by John Robison, was dedicated to James Watt, Black's most illustrious student. S. W.

Contributions of chemistry to pharmacy and medicine. ANON. *Nature*, **138**, 693 (Oct. 17, 1936).—The Hanbury Gold Medal of the Pharmaceutical Society of Great Britain has been awarded to Dr. F. Pyman. Dr. Pyman reviewed the contributions which chemistry has made to pharmacy and medicine during the twentieth century. He pointed out that only within the last one hundred thirty years has it been possible to replace crude drugs and pharmaceutical preparations with pure chemical compounds isolated from them. Successive British Pharmacopeias have included fewer and fewer crude drugs and galenical preparations. Dr. Pyman stated that Robinson's improved methods for the production of tropinone have brought the time nearer when synthetic atropine and cocaine may be commercially available. He believes that, although laboratory products will produce some results not otherwise attainable, the original vegetable or biological preparations, such as tinctures of nux vomica and digitalis and extract of ergot, "will have their place in medicine and may well produce physiological effects which cannot be obtained by their isolated active principles." M. E. W.

RECENT BOOKS

MODERN CHEMISTRY. *Charles E. Dull*, Head of Science Department, West Side High School and Supervisor of Science for the Junior and Senior High Schools, Newark, New Jersey. Fourth edition. Henry Holt & Co., New York City, 1936. xliii + 745 pp. 390 figs. 12.5 × 18.5 cm. $1.80.

This well-known textbook of high-school chemistry, whose third edition appeared in 1931, was first published in 1918. The author claims for the scope of the book: (*a*) an introduction to the study of chemistry, not alone for specialization, but for its cultural value; (*b*) a practical study in which fundamental principles are not neglected; (*c*) the development of the chemical theory in a clear, concise, and logical manner; (*d*) the presentation of material needed to meet college entrance requirements.

The book is arranged in forty-two chapters which may be classified as follows: Part I, introduction and chemical theory, chapters 1–13 (205 pp.); Part II, study of non-metals, ionization and the periodic classification of elements, chapters 14–29 (285 pp.); Part III, the metals, chapters 30–40 (188 pp.); Part IV, carbon compounds, chapters 41 and 42 (67 pp.).

At the beginning of each chapter a short vocabulary of the unfamiliar words is given to aid the student and at the end a summary of the important facts and principles developed in the chapter. The questions and problems which follow the summary are divided into two classes: "Those given in the A-Groups are not difficult for any pupil. The questions and problems given in the B-groups may be assigned as an extra group for the more capable pupil or for those who work more rapidly." In some instances, references are given as supplementary projects. At the end various useful tables are appended.

The plan of the arrangement and presentation of the material follows to a large extent the traditional method. The chemical theory is developed mainly through the study of oxygen, hydrogen, and water. Acids, bases, and salts are introduced before ionization, which is taken up after the study of nitrogen and its compounds, and carbon and its compounds, as late as page 343, a procedure which is of dubious value. The periodic table is not introduced until after the study of sulfur and its compounds and the halogens. Then follows the study of the metals and the organic compounds.

There is a good attempt to introduce modern views and theories. The achievement, however, falls short of the aim, because no use is made of principles in explaining the large amount of factual material which the book contains. The electron theory of matter is briefly given at the very beginning (pp. 28–30) but no use is made of this concept in explaining oxidation and reduction (pp. 47, 75, 264–270, 350, 359, etc.), the activity series. etc. Again, the student, at the beginning is informed (p. 73) " 'heavy hydrogen'—in its chemical behavior—is much like ordinary hydrogen, but it is twice as heavy. It combines with oxygen to form 'heavy water.' " The statement is meaningless unless the matter of isotopes is explained, even in a somewhat rudimentary fashion. When isotopes are explained (pp. 436–7) chlorine is used as an example and the opportunity again is

missed to point out that isotopes differing as much as 100 per cent. do show differences in the compounds they form, because already under water, the facts of differences in density, freezing point, toxicity, etc., were given (p. 105).

The same thing is true with reference to compounds formed by sharing electrons. No use of the concept is made. Again, at the end of the chapter on ionization the structure of crystals as revealed by X-ray analysis is treated. There has been in the previous pages (pp. 181–189), a rather good discussion of the electron theory of valence. The sodium chloride on page 347 is represented as molecules which dissociate into ions, "—The sodium atom loses an electron ($Na - e = Na^+$) and becomes positively charged. The chlorine atom gains an electron ($Cl + e = Cl^-$) and thus acquires a negative charge—." At the end of the chapter, under the topic of the structure of crystals, sodium chloride is pictured as "built up of ions held together by electrical attraction" and after showing a picture of the crystal lattice, the brief discussion is ended with the statement that "when such a crystal is melted—the ions which are loosened from their electrical attraction become free to migrate." This last topic is starred, denoting that it can be omitted without affecting the unity of the course. Now, if it was thought advisable to include this factual material, it should have been connected with the ionization of these molecules "made up of ions."

The treatment of the metals is well done. The discussion of organic compounds is subject to the same criticism as in practically all other high-school texts, namely, that no attempt is made to project the material into a background with which the student is already familiar, so that we deal with a vast accumulation of facts with no correlating principles.

The pictures and diagrams are numerous and well selected. Some of the diagrams need better explanations (pp. 255, 304, 314, 679).

The number of errors that have crept in is not excessive. On page 29 the theory of the "planetary" atom is ascribed to Bohr. On page 284, third line from the bottom, the word diamond should read diameter.

All things considered, it is the opinion of the reviewer that the text represents a good work for the beginner in high school. However, the author does not fully attain his aim to "make this book practical without neglecting the fundamental principles." There is entirely too much factual material left "loose and hanging in the air." In addition to the examples pointed out, two of the many can be cited. On page 511, among the uses of sodium, it is stated that "as a catalyst, it converts isoprene, C_5H_8, into artificial rubber." It is difficult to imagine the benefit of the statement that artificial rubber results from "the catalytic action of sodium on C_5H_8" to a student who thus far knows nothing of organic compounds. Finally, the last entry in Appendix B which closes the book, reads, "What is meant by the pH value?" The explanation which follows is neither clear nor adequate. If it was desirable to include a word on pH, it would have been better to merely give pH as an arbitrary scale of relative acidity and alkalinity, for example, pH 1–2 as a strong acid, pH 3–4 as a weak acid, pH 7 as neutral, pH 9–10 as weakly alkaline, and pH 12–13 as strongly alkaline, etc. The overabundance of ill-connected factual material, although it may be practical, usually does not lead to a well-organized exposition of beginning science. This limitation is commonly offset by the instructor.

The work of the publishers is very good. The book is printed on good paper, is attractively bound and easy to read.

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NUTRITIVE AND THERAPEUTIC VALUES OF THE BANANA—A DIGEST OF SCIENTIFIC LITERATURE. Published by the Research Department, United Fruit Company, Boston, Massachusetts, 1936. 143 pp. 17.5 × 25 cm. Paper-bound.

Subject index; 292 references. This pamphlet contains a digest of scientific literature on the subject.

BRITISH CHEMICALS AND THEIR MANUFACTURERS: THE OFFICIAL DIRECTORY OF THE ASSOCIATION OF BRITISH CHEMICAL MANUFACTURERS. Association of British Chemical Manufacturers, 166 Piccadilly, London, W. 1, England, 1937. 466 pp. 13.5 × 21.5 cm.

This book is obtainable gratis by enquirers who are genuine purchasers of chemicals. Copies are only issued from the office of the Association to such enquirers.

OFFICIAL AND TENTATIVE METHODS OF ANALYSIS OF THE ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. *W. W. Skinner*, Chairman of the Editorial Board. Fourth edition, enlarged and revised. Association of Official Agricultural Chemists, Washington, D. C., 1935. xviii + 710 pp. 15 × 23 cm. $5.00 Domestic, $5.50 Foreign.

"The fourth issue of *Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists* ('Methods of Analysis' or 'Book of Methods') is presented in accordance with the plan to publish a revision every five years. This book continues to grow in size and in the diversity of its subject matter in harmony with the widening horizon of official chemists, who compose the Association. The philosophy of the Association, however, remains the same as in the beginning.

"The general arrangement of subject matter follows the plan adopted for the second and third editions. Certain unsatisfactory methods have been omitted, for instance, the method for the determination of fluorine in baking powders. No general method for this determination has been included, since no satisfactory method has been perfected, although specific procedures for its determination under insecticides and waters have been presented as tentative methods. This subject is being intensively studied by the members of the Association and others, and those interested should refer to 'The Journal' of the Association for the latest developments. The methods for beers, wines, and distilled liquors, which constitute Chapter XVII in the third edition, have been assembled in three chapters entitled, respectively, Malt Beverages, Sirups and Extracts, and Brewing Materials; Wines; and Distilled Liquors. Two chapters of the third edition, *i. e.*, XII Fibers, and XIV Paper and Paper Materials, have been deleted because at the present time the work on these materials is not considered to be of sufficient importance to enough members of our Association to warrant coöperative referee work, and further because such methods are being satisfactorily studied elsewhere.

"Attention is called to a few of the additions to the methods which have special significance. In Chapter I, Soils, the method for the determination of selenium is timely, as is also the method for the determination of the acid-forming and non-acid-forming quality of fertilizers, in Chapter II, Fertilizers, because these subjects have assumed special importance during the last two years. The methods for the determination of the phenol coefficient of disinfectants, included in Chapter VI on Insecticides and Fungicides, is an example of a departure into a field of more unusual methods. Chapter XII, Plant, has been materially revised and enlarged, and now includes a method for the determination of lignin. Methods have also been added under the chapter heading 'Nuts and Nut Products.'

"The method for the determination of lead given in the chapter on Baking Powders has been deleted. Only the comprehensive method for lead in Chapter XXIX, Metals in Foods, has been included. The vitamin D assay by preventive biological test in Chapter XXVII, Grain and Stock Feeds, should be noted, as should also the revised and rearranged Chapter XXXIV, Sugars and Sugar Products.

"Another innovation which should later make a valuable addition to the book is Appendix I, which presents methods for the preparation and standardization of solutions. At present only procedures for hydrochloric acid and alkali are given, but with the appointment of a referee on this subject other material will soon be available. A revised and enlarged section on definitions of terms and interpretation of results on fertilizers and liming materials constitutes Appendix II."

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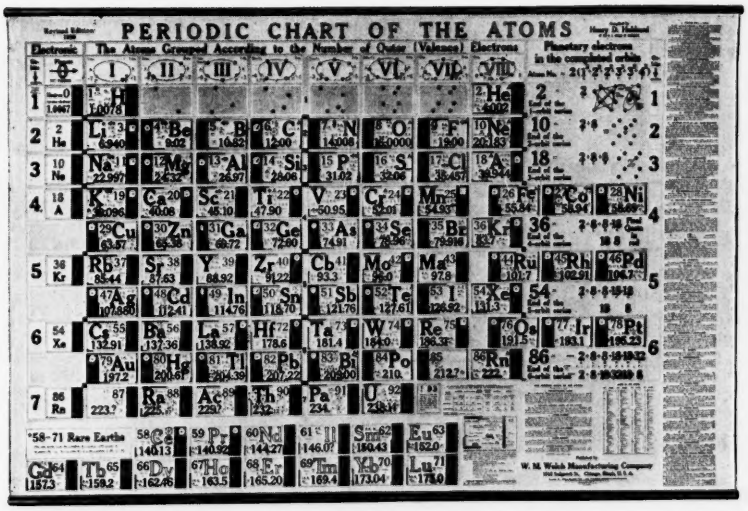

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